GEOLOGICAL SURVEY OF NEW JERSEY.

ANNUAL REPORT

OF THE

STATE GEOLOGIST,

FOR THE YEAR

1889.

CAMDEN, N. J.:
F. F. PATTERSON, PRINTER.
1889.

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(Appointed March 30th, 1864. Died September 22d, 1889.)

IRVING S. UPSON, Assistant in Charge of Office........New Brunswick.
FRANK L. NASON, Assistant Geologist........New Brunswick.

NEW BRUNSWICK, December 31st, 1889.

To His Excellency Robert S. Green, Governor of the State of New Jersey, and ex-officio President of the Board of Managers of the State Geological Survey:

SIR—I have the honor herewith to submit the Annual Report of the State Geologist, for the year 1889.

With high respect,

Your obedient servant,

WM. M. FORCE,

Secretary.

REPORT.

In presenting this Annual Report the Board of Managers are pained to record the sudden death, on September 22d, 1889, of the State Geologist, Dr. George H. Cook, who for more than a quarter of a century filled the position with rare acceptability and efficiency. Since this date, by resolution of the Board of Managers, Mr. Irving S. Upson acts as Assistant in charge of office, Mr. Frank L. Nason continues as Assistant Geologist, and Prof. John C. Smock, who was formerly, for many years, associated with Dr. Cook, acts as Consulting Geologist.

The outline here given of the work done during the year, as well as that proposed for its continuance, had all been carefully planned by Dr. Cook.

The Geological Survey of the State has been continued through the year, and its work has been, as heretofore, to develop and make public the natural products and resources of New Jersey.

In the Annual Report for 1887, it was stated that the Topographic and Magnetic Surveys of the State were completed, and that the reports upon these would be prepared and printed as rapidly as possible. This work is done, and the first volume of the final report of the Geological Survey of New Jersey has been printed. It is an octavo volume of xi. and 439 pages, and contains a report on the Geodetic Survey, by Prof. Edward A. Bowser, LL.D.; on the Topographic and Magnetic Surveye, by C. C. Vermeule, C.E.; and on the Climate of the State, by Prof. John C. Smock, Ph.D. It also contains two maps of the State on a scale of five miles to an inch; one showing its civil divisions, and the other its elevations, mountains, ridges, valleys and plains, together with its rivers and its drainage areas. This volume was distributed during the year just closed, and but few copies of the edition are left.

The second volume is ready for publication. It will be in two parts, the first containing a full Catalogue of the Minerals found in New

Jersey, by Frederick A. Canfield, E.M., and a Catalogue of Plants found in New Jersey, by N. L. Britton, Ph.D.; and the second, a Catalogue of Insects found in New Jersey, by Prof. John B. Smith, and a Catalogue of Vertebrate Animals found in New Jersey, by Prof. Julius Nelson, Ph.D. It is expected that the first part will be distributed early in 1890 and the second as soon after as it can be printed.

The work of preparing the third and fourth volumes has already begun, and they will be published as soon as they can be properly prepared. The third volume will treat of Recent Geological Formations, including Greensand Marls and Water-Supply, and the fourth will be a Report on the Clays found in New Jersey.

So much attention has been given in former reports to the study and description of the geological structure of the rocks of the State, that the work still to be done is mainly in combining and systematically arranging the materials which have been collected by various persons who have made New Jersey a study in former years. This is especially the case with the marl and clay formations in the middle of the State, and the limestones, slates and sandstones in the north and northwestern portions. There are some obscure and difficult points of structure in the red sandstone and the gneissic rocks, but it is thought that important progress has been made in clearing up these difficulties, and that the volumes on structural geology can be prepared as soon as that above mentioned is out of the way, and that one on the economic geology can then properly complete the series.

The prompt publication and liberal distribution of the results of the State surveys have continued to meet the approval of our citizens, and to supply suggestive and needed information. The expenses of printing, mailing and expressage are large, but the returns in the development and wealth of the State abundantly justify the expenditure. The whole system of artesian well-boring was started at the direct suggestion of the Survey, and it has brought inestimable sanitary and pecuniary benefits to the whole Atlantic coast, and has been of great service throughout the State. The description of the location and structure of our fire and potters' clays, and its publication, has caused the development of some of the best clay properties in the country, and has made public our immense stores of the best plastic and refractory materials in the immediate vicinity of the great manufactories and markets of the continent. The preparation and publication of our topographic maps, in advance of those of any other State, have tended to draw attention to the peculiar advantages of New Jersey in its

location, its varied surface, its healthful sea-side and mountain resorts, its water-supply, and its unequaled means of travel and communication. The maps are studied by engineers for projected improvements, by citizens seeking homes in the country, by land-owners who desire to improve or open their properties, as well as by intelligent and inquiring citizens of all kinds who are interested in the development and prosperity of the State. The publication of the condition of our mines, our quarries, our lime production, our marls, our drained lands, our water-supplies and other matters of general interest is continually inciting to new enterprises and the investment of capital, and the notes in regard to soils and the means for their improvement, are helping to develop our agriculture and to greatly increase its products.

The annual and other reports have always been distributed without charge to those who receive them, and are sent on application. Several of the reports, as stated on another page, are out of print, and we can now only supply incomplete sets.

The first edition of the topographic map was all distributed. A second edition has been printed, and by the act of the Legislature of 1888 it was directed to be sold at the cost of paper and printing, to those applying for it.

A large number of maps have been sold upon these terms, and the proceeds are returned to the State Treasury.

The reports and maps are all sent to every public library, as far as known, in the State; to several libraries in New York and Philadelphia, and to many other public libraries outside the State, which have applied for them. In this way reference can usually be had to them.

Pursuant to the act* of the last Legislature (Chapter CXXXVIII.,

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*An Act to provide for the distribution of the publications of the geological and topographical surveys of the state to the several public free schools of the state, and to provide for the payment of the cost and expenses thereof out of the income or revenue of the fund for the support of the public free schools of this state.

1. Be it enacted *by the Senate and General Assembly of the State of New Jersey,* That the board of managers of the geological survey be authorized to furnish to the public free schools of the state, the state normal school, the state model school, the New Jersey school for deaf-mutes, and the Farnum preparatory school, properly prepared copies of the final reports and maps of the results of the said survey under their charge.

2. *And be it enacted,* That said reports and maps shall be furnished on the requisition of the state superintendent of schools, and shall be sent to the clerk of the school district or board of education in which the schools are located, and received by him as the property of the district or boards and for the use of the schools.

Laws of 1889), the publications of the Geological and Topographical Surveys have been distributed to the several public free schools of the State.

Of the subjects coming within the province of the Geological Survey, notes are presented in this report upon the following:

I. Geodetic Survey.

II. Geological Studies of the Archæan Rocks.

III. Geological Studies of the Triassic or Red Sandstone and Trap Rocks.

IV. Drainage of the Great Meadows in the Pequest Valley; Drainage of the Low Lands on the Passaic, above Little Falls.

V. Water-Supply and Artesian Wells.

VI. Publications of the Survey.

VII. Assistants.

VIII. Expenses.

IX. Statistics of Iron and Zinc Ores.

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3. *And be it enacted*, That the said reports and maps shall be furnished at the cost of publication, and the cost and expenses thereof shall be paid out of the income or revenue of the fund for the support of the public free schools of this state, on the presentation of the bills therefor, audited by the said board of managers, and approved by the state superintendent of schools.

4. *And be it enacted*, That the comptroller is hereby directed to draw his warrants upon the treasurer of the school fund for the above-mentioned appropriations and expenditures when they shall severally become due and payable; and the said treasurer is directed to pay the same out of any moneys now in his hands, or which may come to his hands, as income or revenue from the investments of the school fund.

5. *And be it enacted*, That all acts inconsistent with the provisions of this act are hereby repealed, and that this act shall take effect immediately.

Approved April 9th, 1889.

I.

GEODETIC SURVEY.

REPORT BY PROF. E. A. BOWSER.

NEW BRUNSWICK, N. J., December 19th, 1889.

During the present season, the U. S. Geodetic Survey of New Jersey has been continued southerly and westerly from the line Hammonton-Newfield, which was reached in 1887. As no appropriation was made for the Survey in 1888, no work was done during that year.

The first work done on the Survey this season was the building of an observing tower 64 feet in height, at Williamstown, to enable us to see over the high timber on the line to Colson's, most of this timber being 100 feet high.

When the tower was completed, the observations were begun at Williamstown for measuring the horizontal angles to the primary stations, Pine Hill, Berlin, Hammonton, Newfield, Colson's and Taylor's. A careful reconnoissance had to be carried on at the same time to select the station Taylor's, and to ascertain whether it could be seen from Colson's and Pine Hill, and also whether it commanded a good view of the old primary stations, Lippincott and Burden. Observations were also made upon the following tertiary signals: Clayton church spire, Glassboro church spire, Hammonton church spire (white), Hammonton church spire (brown), Berlin church spire, Vineland church spire, City Hall tower (Philadelphia), Monroe and Whig lane.

During the season a reconnoissance was carried on to determine how high it will be necessary to build the observing towers at Colson's, Taylor's and Bridgeton. As there is much very tall timber on the lines connecting these stations, towers at least 64 feet high will be necessary, and vistas through the tree tops will have to be opened.

II.
GEOLOGICAL STUDIES OF THE ARCHÆAN ROCKS.

BY FRANK L. NASON, A.M.

HISTORICAL REVIEW OF THE SURVEY IN THE ARCHÆAN HIGHLANDS FROM 1836 TO THE PRESENT TIME.*

In the Annual Report of the State Geologist for 1836, Professor Henry D. Rogers gives the first description of the "Primary Rocks" of New Jersey. His report was brief, as any student of geology could easily imagine, for geological problems in the early days of the science were regarded as being much more simple than they are to-day. Interest chiefly centered in the younger fossiliferous rocks, for in these lay the characters which revealed the life history of the world. From the lowest Silurian rock to the most recent formation by the sea-side or lake shore an almost continuous history was revealed through the continually changing and advancing forms of life. Consequently any rock which was too crystalline to show readily traces of life was at once thrown into the class of rocks variously designated as "Primitive," "Primary," "Azoic," &c., which was supposed to represent the first crust of the earth. That the subject of what is now known as Archæan Geology was then regarded as simple, is amply shown in that report. The structure of the whole formation as represented by his sections across the Highlands† shows every range to be composed of simple anticlines with their respective flanks dipping northwest and southeast.

Hardly any attempt was made by Professor Rogers to classify the rocks of this field, except by making the very questionable division into gneisses and granites.‡ Even in this classification the basis was

* For brief historical sketch, see Annual Report State Geologist, for 1885, pp. 37 to 40.

† Final Report State Geologist of New Jersey, for 1840.

‡ See Annual Report State Geologist, 1840, Chap. I., p. 12.

extremely arbitrary, for the assumption was made that a foliated structure indicated or even proved sedimentary origin.

Granites,* greenstones, and metalliferous deposits of all kinds, were by him considered as of igneous origin, and were, in accordance with this idea, designated as "mineral *veins* or *lodes*."

His studies of the crystalline limestones led him to regard them as metamorphosed blue limestones of Silurian age. This conclusion was perfectly deducible from his premises, for they (the limestones) are in most cases intimately associated with zinc and iron ores. Though many geologists do not agree with him, regarding his crystalline limestones as Archæan, his position has by no means been disproved. A careful reading of his report shows the most minute observation and recording of facts, and the accompanying geological map and sections carry one far in the realization of the amount of information collated; and the errors of inference with regard to the analysis of the Archæan problem may well be, for the most part, accredited to the times rather than to the man.

During the years 1854, 1855 and 1856 the geological survey of the State was again prosecuted under the supervision of Dr. Kitchell as State Geologist. Little definite advance was made in the study of the Archæan save, perhaps, in the discovery and recording of new facts relative to the boundaries of the formation, and the distribution and modes of occurrence of the metalliferous deposits.

New contacts between formations widely separated by time were pointed out, and records of the advance of mining interests were made. But there was no more definite comprehension of the Archæan problem. It was still regarded as simple, and the same laws of stratigraphy were applied as in the case of the well-recognized sedimentary rocks.

In 1864 the Survey was again re-organized, with Professor Geo. H. Cook as State Geologist. The facts collated and classified during his administration from 1864 to the final report of 1868 are to be found in the "Geology of New Jersey," Newark, 1868.

In this report the rocks of the Archæan are referred to as "Azoic," in sharp contrast with the "Primitive" of Rogers. Although this marks a decided progress in the comprehension of the Archæan problem, it still falls short of a full grasp of it. By the use of the term "Primitive" or "Primary," Rogers assumed that the gneisses, so

* See Annual Report State Geologist, 1840, Chap. I., pp. 21 and 36.

called, of this formation were actually the first sedimentary rocks deposited upon the crust of the earth. In this view of the case the possibility that these gneisses, even if sedimentary, were but the detritus of older sediments, as these might be the fragments of deposits older still, was entirely lost sight of or was not considered worth discussion.

While the term "Azoic," employed by Professor Cook in 1868, was entirely non-committal on the point of the derivation of the Archæan rocks, it committed the author to assumptions in every way as gratuitous as the "Primitive" of Rogers; for this term "Azoic" unavoidably carries with it the idea that throughout the vast extent of Archæan time no trace of life, plant or animal existed, yet it fully recognizes the untenability of Rogers's term, and is thus, in spite of its own grave error, a positive advance in geological science.

By comparing the geological map which accompanies Professor Cook's report with the one published by Professor Rogers, the reader will be impressed in a most lively manner with the increase of detailed knowledge of the Archæan. In the latter a great part of the Archæan is represented as islands lifted above the younger rocks which surround them. Boundaries are arbitrarily made and the bold dashes of geological color testify with no feeble voice to the fact that geological science was more of the library than of the field. The collected facts of Rogers's and Kitchell's surveys, coupled with those of Professor Cook and his assistants from 1864 to 1868, show to excellent advantage in the geological map published in that year. A comparison with the last map published in 1889 shows changes of only minor importance. In the map of 1868 the connecting points between the isolated Archæan islands of Professor Rogers are completely traced out, and succeeding surveys have confirmed the fidelity to facts which this map shows. In short, with the lack of data then at hand in the form of accurate topographic maps, one can only wonder that such a high degree of accuracy could have been attained. When we come to a careful study of the chapters on the Azoic rocks themselves, progress is found to be neither as decided nor as satisfactory.

Reference in this connection has already been made to the terms "Primitive" and "Azoic;" and we find as we go farther that, as in this case, though statements may differ in kind, they are yet statements of credence rather than of positive knowledge. For, if Professor Rogers arbitrarily assumed, in 1840, that metallic deposits were

injected dykes and were thus to be classed with other eruptive rocks, the assumption that these deposits were *bedded* and of *sedimentary* origin was no less arbitrary. The same may be said of the crystalline limestones, for the report of 1840 had not sufficient data to prove the extreme metamorphism necessary for its hypothesis; neither are facts yet sufficient to push these rocks into the Archæan. On one point both reports agree: the sedimentary origin of the Archæan gneisses and the igneous origin of the granites and greenstones. Even if the report of 1868 did nothing more than to publish the improved geological map, and it assuredly did do more, the bulk of the volume as compared with the report of 1840 testifies strongly to the increased number of facts collected and to the necessity of such collections before accurate maps can be obtained and work done.

As a whole, and in spite of grave discrepancies, the student of geology will find in these two volumes* landmarks which define most exactly progress in geological science; and that not in New Jersey alone.

Although the report of 1868 was called "final," the Survey has been continued to the present date under the direction of Professor Cook.

The results of this Survey, extending over a period of twenty-two years, have never been formally collected, but have been published from time to time in the Annual Reports. This, of course, excepts map-making and publishing, as well as several monographs, either the direct work of the Survey or based on material supplied by the Survey.

Though the attention of the Survey was for the greater part of the time diverted from the Archæan by press of work in other directions, yet in 1873 a map was published in connection with the report, entitled "Northern New Jersey, Showing the Iron Ore and Limestone Districts." This map marks the first attempt in the New Jersey field to group together in any way the allied rocks of this extensive formation. In it there are recognized three divisions of the Archæan, viz., gneisses, iron-bearing gneisses and the crystalline limestones. There is nothing, however, either on the map or in the report, which would indicate that this division was other than provisional. This must have been the case, since work on the topographic sheets had already been begun, though nothing but preliminary work had been done in the Archæan. Yet, imperfect as this map was in many

* Final Report of Rogers, 1840. "Geology of New Jersey," Geo. H. Cook, 1868.

details, the appreciation of it by the public was expressed in unmistakable terms. It is not now possible to obtain a copy of this report.

In the reports of 1883 and 1884 still more evidence is found of the study of what may be called differential characters of the Archæan rocks. On page 33 ("Rocks," p. 31, Annual Report State Geologist, 1883) the results of these studies are summed up. Of this division the writer says: "The division of these Archæan rock outcrops into groups or belts according to their specific characters, has been attempted, but thus far without complete success. Following the analogy of the newer formations, it ought to be possible to define the limits of well-marked varieties and describe their outcrop. The division following the feldspathic and hornblendic varieties appears possible, as their outcrops are so easily recognized by the rock, soil, structure and even flora. Many lines have been followed in hope of detecting some order in the succession or the alternation of these more common varieties of rock." Following this is the description of four of the most readily recognized rocks of the Archæan.

In the report for 1884, p. 65,* a definite suggestion is made that the results of the studies of the differential characters of the Archæan be graphically represented in the form of a geological map which would show the relative position and extent of the various rock types or groups. It was feared, however, that on account of widely-concealed areas, and of the faulting and displacement of the rocks, this would be impossible. The *suggestion* of itself, however, marks a long advance in knowledge of this formation.

The reports of 1885 and 1886 mark a decided epoch in the study of the New Jersey Archæan. The completion of the topographic maps by the Survey enabled the geologists to see definitely and as a whole what before could only be seen part by part. In other words, by means of the contours the whole field could be embraced by a single glance. The comparative heights of the mountains, their general trend and their relations to each other were almost perfectly shown. By the aid of these maps what before seemed a hopeless task, namely, the mapping of the various rock groups, appeared then to be resolved merely into a question of how much time and labor could be put upon it.

In the report of 1885, Dr. N. L. Britton and Mr. F. J. H. Merrill

* See Annual Report State Geologist, 1884.

began the systematic study of the field with these maps. Section lines were drawn and collections of type rocks were made along these lines. These rocks, thus collected, were compared with collections previously made by Professor Smock. The result of this comparison was a table of the various kinds of rocks found.*

The report of Dr. Britton for 1886 gives an account of additional field-work, the results of which are summarized in a classification of the Archæan rocks.† He divides them into a lower "Massive Group," a middle "Iron (Magnetite) Bearing Group," and an upper "Gneissic and Schistose Group."

As will be shown later on, the groups are not mutually exclusive, but cut into each other. This is true not only in particular cases, but can be shown to be true throughout the whole extent of the Archæan. Two colored maps of limited areas of the Archæan show the distribution of the rock groups of these areas as given in his report.

The error of this division of the Archæan and the assumption of the sedimentary origin of the foliated rocks is comparatively slight when viewed in the light of the progress that has been made as the result of accumulated facts extending over so many years. If the maps and the proposed classification of Dr. Britton have done no more, they have shown clearly and positively that a detailed division can be made and mapped, but that more data must first be obtained.

This brief sketch of the history of the New Jersey Geological Survey, although confined chiefly to the Archæan Geology, shows clearly that the comprehension of the work of the geologist has been a continually growing one. If errors have been made they are not to be taken as signs of decay but rather of growth, since they show that problems are being viewed from every possible standpoint. This is evident, since errors pointed out lie not in the facts observed and recorded, but in the inferences made from them. They become thus merely incidental and not at all fundamental, since any one can be corrected without in any way disturbing the harmony of the work in the past or in the present. The observations made and recorded by Rogers in 1836 regarding his studies of iron mines and other metalliferous deposits, are just as authentic and reliable to-day as when he made them fifty-eight years ago. The fact that he interpreted these observations as pointing to igneous injections rather than to a sedi-

* See Annual Report State Geologist, 1885, p. 40.

† See Annual Report State Geologist, 1886, p. 77.

mentary origin, detracts absolutely nothing from their value. The exact lines of the development of the survey from 1836 to the present time may be summed up briefly as follows:

First. The recognizing and mapping of the various formations by Professor Rogers from 1836 to 1840 comprises what may be called the preliminary work or studies of the external characters of the Archæan.

Second. From 1840 to 1868 this line of work reached its culminating point in the geological map of 1868.

Third. The perfecting of this work in 1868 necessitated the collection of facts which culminated in the completion of the topographic atlas in 1888.*

In other words, the development of the Geological Survey had reached such a point that farther progress was barred until more correct maps were had.

Fourth. From 1868 until the present time the work done in the Archæan has been confined to the internal structure and to the relations of the different members one to another.

This work has not been completed, and it is of the utmost importance.

The status of the work at the present is this: Sufficient data have been collected to show that the rocks of the Archæan are not homogeneous, but that there are belts which are similar and persistent. These belts need to be traced out, carefully studied and described and then laid out upon the new topographic maps. In other words, in order to realize the highest benefit from the work a new geological map is needed upon the scale of one mile to the inch. The *structure* of the Archæan is, as yet, comparatively little known. River "cloves" like the Delaware, the Pequannock, the Ramapo and the Hudson; river valleys like the Pequest, the Pohatcong, the Musconetcong, the Wanaque and others; do these divide the Archæan by chance or are there fractures in the rocks which determine their courses?

A question of greater immediate importance presents itself. Miners often have trouble in following their leads of ore. It suddenly "cuts out." Shall it be looked for above or below, to the east or to the west? Does a certain line of mines like the Chester mines begin abruptly at Chester and end at Mt. Hope? Is there a probability that between

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*The topographic maps of the Archæan Highlands were completed in 1884 and 1885.

two widely-separated mines like the Hurdtown and the Ogden deposits, there are other deposits which give no known sign of their presence, even with the miners' needle? The dip or "underlay" of the beds, their pitch* or inclination to the northeast, and other points, seem to indicate, at least, a close relationship to the rocks which lie for a great distance on either side of them.

Again, there are beds of ore which run high in phosphorus and others which run low. One bed lies in close connection with white limestone and zinc, another has no trace of either. Can these beds be correlated and grouped in any way? One of the most serious obstacles to successful mining is the "pinching out" of veins or beds. That is, the foot and hanging-walls gradually approach each other until the ore is reduced to a narrow ribbon or disappears altogether. Oftentimes thousands of dollars are spent drifting along this narrow bed, and the work is finally abandoned.

It is not certainly known that accurate knowledge of the country will solve these problems, but there is more than a strong probability that this knowledge will be directly available in many cases.

To the practical miner it may seem absurd to attempt to locate a lost bed of ore by a study of the rocks on the Delaware or a section along a line of railroad. But it is to be remembered that the disturbance which has caused the trouble in the mine is not local in its effects, but that it extends for miles, and data which may be obscure or lacking at a particular place may be abundantly and clearly found at a distance.

Before results of this kind can be obtained there is much work of a very difficult nature to be finished or at least carried to the point of intelligent comprehension.

It has already been noted that Professor Rogers assumed iron ores and other ores to be igneous or eruptive in their origin, while Professor Cook held the opposite. This same divergence of opinion covers the whole of the Archæan rocks, gneisses and granites alike.

Nothing but hard, close work, both in the field and in the labora-

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* Dip and pitch have already been defined as applied to ore and to rock-beds. If one calls to mind the ordinary peak-roofed or Λ-roofed house, the slope of the roof will correspond to the "dip" of the geologist or the "underlay" of the miner. If now the ridge of the roof be tilted and the slopes of the roof as well, this second inclination will represent the "pitch" of the ore-bed or of the rocks. The slopes or sides of a mountain, for instance, might be to the northwest and to the southeast, while, if the axial crest was inclined to the northeast, the rocks would be said to "pitch" in this direction and "dip" in the other two directions.

tory, will ever settle these points, and it is fully as important to the practical man as to the student that this knowledge should be gained.

There is no doubt but that when Professor Cook was first assigned to the study of the marl and clay-beds by Dr. Kitchell, thirty-six years ago, the work was considered by practical men to be of no value. Yet to-day, as the results of these labors, water lines are drawn across the whole of the southern part of the State, and the depths to which artesian wells must be sunk to obtain a supply of pure water is accurately known. Clay and marl-beds have also been as accurately outlined, and the work has beyond a doubt added millions to the wealth of the State. There is no reason why further detailed surveys and re-surveys should not lead to results in every way as beneficial.

The plan of the survey, in addition to the careful attention which has always been given to economics, is to carry to completion the work already begun. This involves the following points:

First. A careful study of the rocks and minerals of the Archæan.

Second. A careful retracing of the boundaries of the Archæan, its possible subdivisions and the other formations of the State upon the new topographic sheets.

Like careful work in the Archæan may yield results in every way as valuable.

For the past two years the work, with this end in view, has been pushed as vigorously as possible. The results are given in detail in the following report on "The Field-Work in the Archæan."

REPORT OF FIELD-WORK IN THE ARCHÆAN HIGHLANDS.

In accordance with the plan of the survey outlined by Dr. Cook, the work of studying the complex structure of the Archæan Highlands of the State has been continued this year.

During a part of the summer of 1888 Mr. Uno Sebenius, a mining engineer, was employed in tracing lines of magnetic attraction and in noting the rocks in which this attraction occurred. The object in getting these lines of attraction may be more readily understood after the following explanation:

The iron-ore beds of the State have been found to lie in parallel ranges, extending in a northeast-southwest direction across the State. These ore-beds do not appear to be continuous, but are usually more or less widely separated along the line of strike. In Figure 1, let *a*,

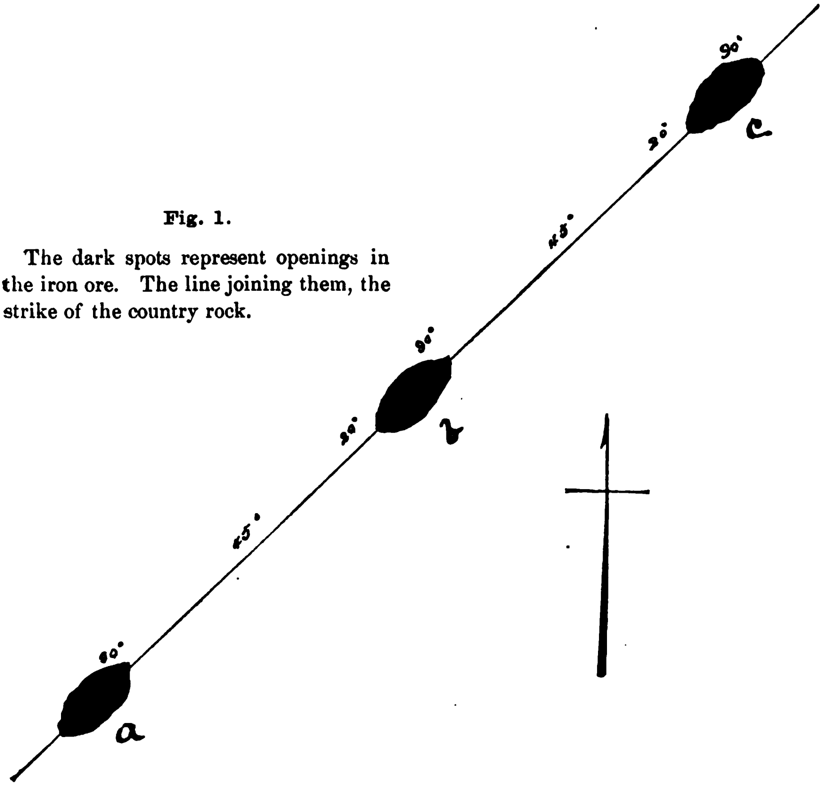


Fig. 1.

The dark spots represent openings in the iron ore. The line joining them, the strike of the country rock.

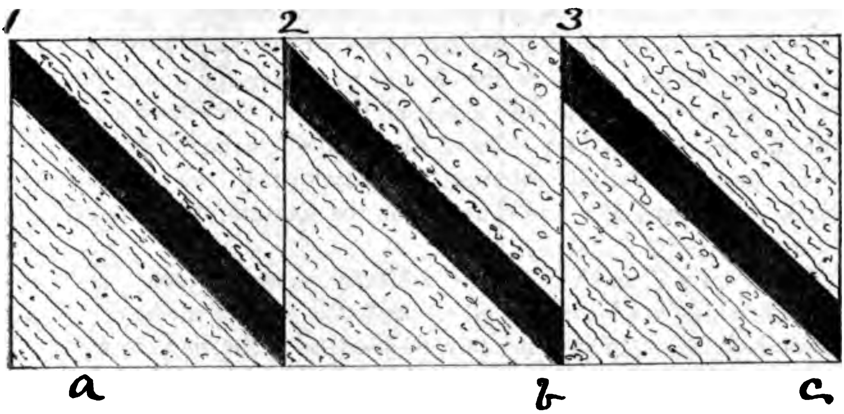


Fig. 2.

The dark bands represent iron ore.

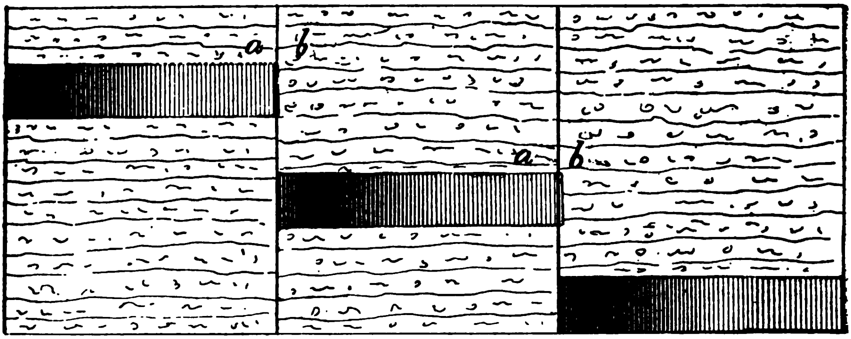
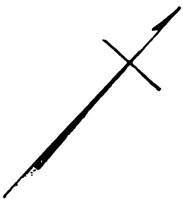


Fig. 3.

Represents ore-beds faulted by lateral displacement.



b and *c* represent these iron-ore beds worked on the same line of strike. Let us suppose each to be worked. Each deposit as it is worked downwards will show a pitch* to the northeast of varying steepness of from 10° to 45°. By running a dipping-needle over the intervening points between *a* and *b* and *b* and *c* it is found that the attraction varies from 90° at one mine to 0° before the other mine is reached. This variation will be noted between any two mines on the same line of strike.

By studying the pitch of the ore and by getting the line of attraction from point to point, and also stúdying the country rock, one may decide that these ore-beds lie as in Figure 2, where the mines *a*, *b* and *c* are shown in vertical projection. The dark bands here represent the beds of ore, and *1*, *2* and *3* represent the location of the mines in Figure 1.

In Figure 3 another kind of difficulty is encountered. In this figure, which is a horizontal plan, the darker parts of the band represent beds of ore which lie near the surface. The lighter portions are more deeply buried on account of the ore's *pitching* under or below the surface. In this case the successive mines, instead of lying in line, are seen to lie successively to one side of the line of strike.

* For definition of pitch, see p. 19 of this report.

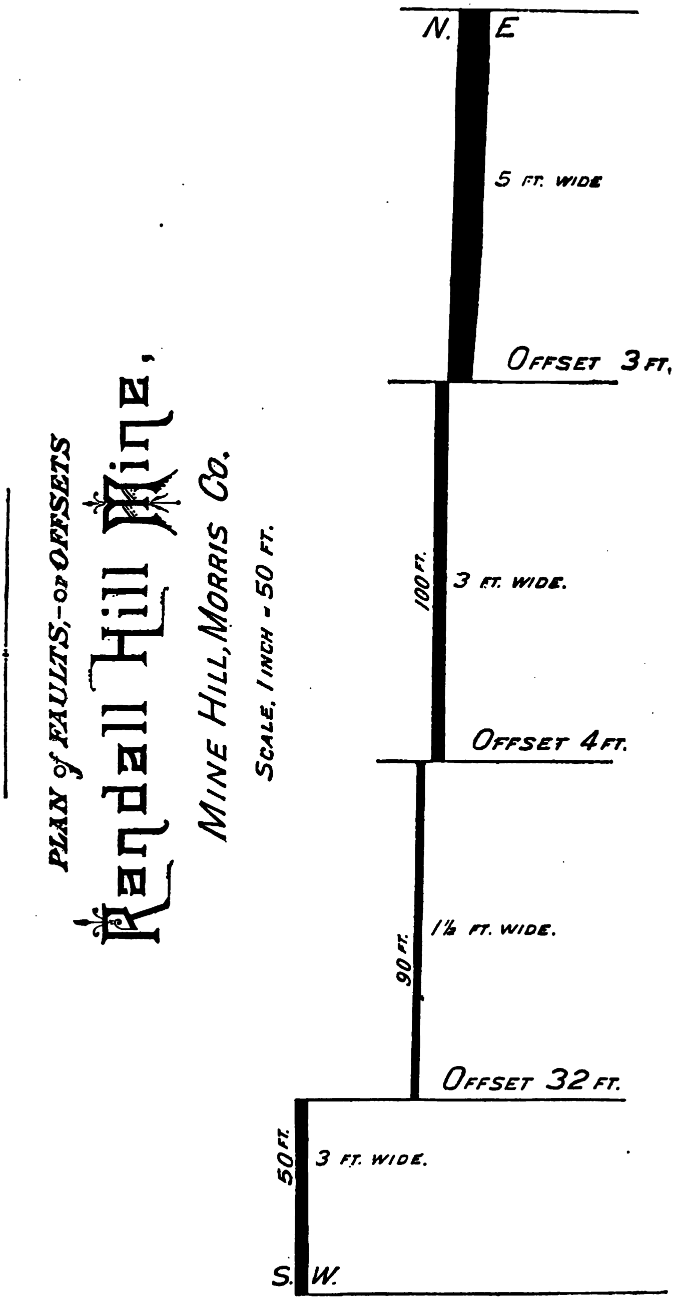
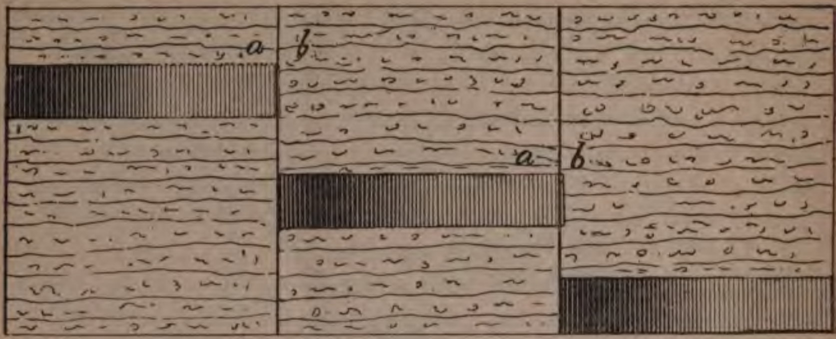


Fig. 3'.
(Copied from Annual Report State Geologist, 1888.)



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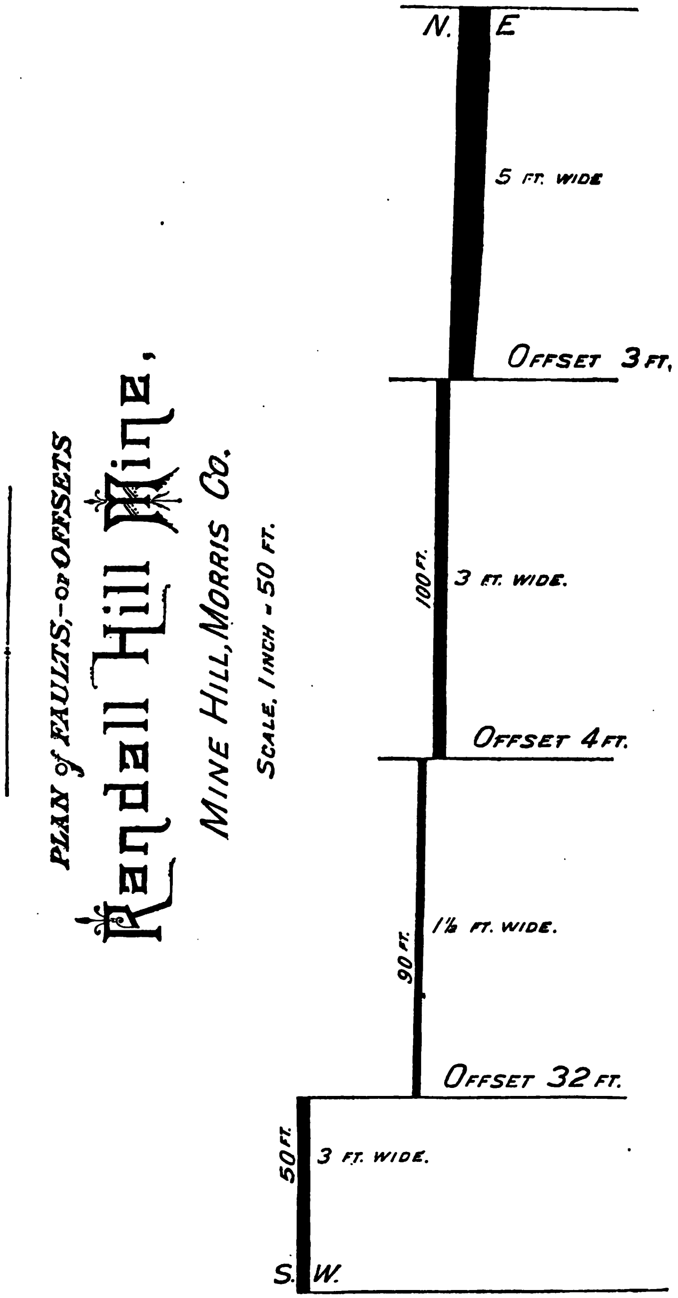

Fig. 3'.

(Copied from Annual Report State Geologist, 1888.)

If a dipping-needle be employed, it will oftentimes be found that the attraction abruptly ceases, and is not resumed till at a considerable distance to one side or the other of a line of strike. The inference is that the ore body has been broken in two, and has been thrust sharply to one side. Figure 3′ shows such a system of offsets from Randall Hill mine, Mine Hill, Morris county, N. J. Offsets of this kind are known as faulting by lateral displacement, when the country rock, as a whole, and the contained beds are thrust sharply to one side. In Figure 2 the faulting there is known as faulting by vertical displacement. These two are often combined, so that the rock and contained ore-bed are vertically displaced, and thrust aside as well. A careful study of the strike and pitch will usually reveal the direction and amount of faulting, and, whatever its direction, these results, once obtained, cannot fail to be of great practical importance to the miner.

Aside from the immediate practical value of this work, our knowledge of the structure of the country is greatly enhanced if we can trace these lines of attraction and similar rock for great distances.

During the months of October and November of 1888 I was with Mr. Sebenius in this field, studying the inclosing rocks and making collections of them for future study. In May, 1889, I again resumed work in the field, and, with slight interruptions, continued field-work till prevented by the weather. The territory covered is nearly as follows:

The greater part of May was consumed in surveying Ramapo mountain, from Suffern, N. Y., to Pompton, N. J., on the south, and the country between the Ringwood mines on the east, the New York and Greenwood Lake railroad on the south, and Greenwood lake and the State line on the north and west.

Wawayanda and Hamburg mountains were again gone over and some time spent in tracing out the boundaries of the white limestone at Franklin Furnace.

The greater part of the months of June and July were spent on Jenny Jump, Scott's and Marble mountains. In August the country along the west shore of Lake Hopatcong was surveyed.

September, October and November were consumed in a survey of the country lying between the Delaware, Lackawanna and Western railroad, on the south, and the New York, Susquehanna and Western, on the north.

The country on either side of the Pequannock river, a half mile

north and south, was carefully gone over, to secure, if possible, data which would prove a fault along the line of the river.

The manner of conducting the survey has been somewhat different from the plan usually pursued. No attempt whatever has been made to construct section lines directly. A topographic map has been taken, and from some central point every hill has been gone over. Specimens of the principal rocks have been taken from either slope, and from the summit of the hill. No less than two hundred and fifty hills have thus been traversed.

The specimens thus collected were noted on the map and in the field note-books. By comparing them in the survey laboratory, and by careful study, it is hoped that results will be attained for the final report, which have hitherto lacked sufficient proof to make them wholly reliable.

It is believed that there is now proof in the laboratory of the Survey that will establish beyond doubt the fact that the Pequannock river flows in a fault. It is also believed proof is held, in the shape of rock collections and field notes, to establish long lines of fracture running parallel to the northeast-southwest trend of the formation. These facts have been secured, not by running section lines directly, but by collecting type rocks wherever found. Section lines can thus be readily constructed at any time, since the specimens can be selected and placed in order by reference to maps, while a reference to the note-book gives the dip, strike, and rocks associated with the specimen. The work is more exhausting, physically, since no point of observation is omitted, and more time is consumed. But it is believed that more satisfactory results can be obtained in this way than in any other. One thousand specimens have been collected in this way, labeled and placed in the laboratory for study.

The collection of these rocks is rendered necessary by the extreme complexity of the structure and mineral composition of the Archæan rocks. In spite of the fact that experienced miners and prospectors regard the rocks of the Archæan as all being the same and denoting them all as "gray mountain rock," there is a puzzling variety. Though there are seventy-six rock-forming minerals recognized, it is rare that more than three to six of these minerals are found in any one rock. Yet, where only three or four minerals unite to form a rock, the proportions vary to such an extent that, in the absence of a continuous line, it is difficult to positively identify them. Thus, for

example, the enclosing or "country rock" of the Mount Hope mine is, at present, assumed to be the same from the Dickerson and associated mines at Ferro Monte, to the Howell and other mines on Copperas mountain. In these places mentioned, the rock consists principally of quartz, feldspar and magnetite. Yet, in other places, on Scott's mountain, for example, a rock similarly situated, having the same color and general appearance as the rock from Mount Hope, has the magnetite partly replaced by a mineral known among miners as "black-jack," technically called hornblende; biotite is also present. Roughly speaking, the rock is the same; yet, in the absence of all but field study, this cannot be definitely asserted.

In order positively to affirm similarity or dissimilarity, much laboratory work must be done. A careful macroscopic study of each specimen, in order that whatever can be learned of it by the unaided eye, or the eye aided by a common lens or magnifying glass, may be familiarized. Yet in many cases the rock is so fine grained that its structure, much less its mineral composition, cannot be learned. In this case resort must be had to the microscope. In addition to the microscopical examination of the rock, a complete, or sometimes only a partial chemical analysis must be made; and, finally, its specific gravity must be learned. As has already been stated, one thousand specimens have been collected, numbered and registered in a catalogue and note-books, and their localities exactly placed on maps. No more thorough examination has been made than has been possible in the field while collecting them. Further work is reserved for the laboratory. The chemical work will be done in a laboratory which has already been fitted up. The work of preparing the rock sections is well under way.

About one thousand specimens have been nearly completed for examination.

Each slide has cut upon it with a diamond pen the number of the rock from which it was taken, thus furnishing a ready means for recognition.

Even after the final report of the Survey these rock specimens and slides will be of great value to any one who wishes to pursue farther the study of the geology of the State.

FAULTED STRUCTURE DETERMINED BY LINES OF GRAPHITE AND IRON ORE.

As has been before stated in other reports of this survey, the great difficulty in proving faults and folds in the Archæan rock is the entire absence of fossils. Lithological similarity alone is not sufficient proof. But if long lines of rocks possessing either constant similarity or dissimilarity can be determined, and the relations of these lines become recognized, the object is in a fair way of being accomplished. In Morris county such lines have been established. That is, three distinct lines of iron-ore beds and rock, together with a long line of graphite rock, have been located. Repeating briefly the description of the direction of the graphite, we find a striking parallelism to the lines of iron ore. The graphite begins near a mine located at High Bridge, just northeast of Clinton, and from there extends nearly due northeast to Fairmount. From this point the line turns 3° further east to Washington valley, northwest of Morristown. Between this point and a point on the Morris canal, one and a half miles north-northwest of Denville, the graphite rock has not been found, and it is doubtful if it exists. From this point to Stickle's pond, one mile east, it has been continuously traced the whole of this distance—seven miles.

From Cokesbury iron mine a line of iron runs, nearly parallel to the graphite, through Fairmount and the Langdon mine, where it turns a little east. It then runs through the Combs, Munson, Swede's, Beach Glen, Richter, Cobb's and Pike's Peak mines. At the Combs mine the line changes farther to the north.

From the Hacklebarney mine, near Chester, another rather irregular line begins. This runs northeast to Ironia. At this point the direction changes to north-northeast to Port Oram. From here, through Mount Hope, the line, bending a little to the east, goes to the Howell mine, on Copperas mountain.

From Ironia a line of mines runs nearly due northeast, in apparent continuation of the Chester mines, and at the Sigler mine, near Dover, changes to north-northeast, and passes through the White Meadow and Hibernia mines.

The country rock southeast of Ironia has not been examined, but the inference is that it is the same as the rock from Ferro Monte, Cranetown and near Munson's mine, to the northeast. The Mount

Hope country rock certainly extends from Ferro Monte to the Howell mine, as specimens have been collected and carefully compared in the laboratory. From Swede's mine, near Dover, the country rock is the same through to Pike's Peak mine, at Stickle's pond.

From northeast of the Delaware, Lackawanna and Western railroad the Mount Hope, Hibernia and Beach Glen beds are parallel to each other and to the line of graphite, and all of them cease abruptly southwest of the Pequannock river. The bending of these lines from a constant direction also exhibits a remarkable similarity. A line from Morristown running west, 25° north, would pass through Washington valley, Combs' mine and Ironia. These points are not absolute, but the deviation from them is certainly not great, and very near these points the lines of iron ore and graphite bend towards the north from their previous courses. Along the line of the Delaware, Lackawanna and Western railroad from Denville to Dover and Port Oram, these lines again change, but this time to the east of the last-mentioned course. Whether the graphite occurs between Denville and Washington valley or not, there is a deviation of the line from near Rockaway to Stickle's pond as compared with the one from Fairmount to Washington valley. That this last-named line from Denville to Port Oram is a fault line there can be no doubt. It extends farther to the northwest by Stanhope and Andover. Between Stanhope and Lockwood the rocks change abruptly from the usual northeast strike, the trend here being nearly north and south.

Northeast of this line of faulting, the Mount Hope, Hibernia and Beach Glen mines run parallel to the line of graphite. All of them end abruptly near the Pequannock river. From the line of the Delaware, Lackawanna and Western railroad each one of the above-mentioned lines of iron mines and graphite have been traced almost continuously. If these facts be joined with the almost unexceptional pitch to the northeast of the beds of iron ore,* the similar pitch of the axial ridges of the mountains, there is all but positive proof of long lines of northwest-southeast fracture extending across the Archæan.

Northeast of the Pequannock river a line of graphite rock begins on hill 833 east of Pompton station (New York, Susquehanna and Western railroad), and runs to near Hillburn, N. Y. In a railroad cut, on the New York and Greenwood Lake railroad, one mile north

*See Annual Report State Geologist, 1883, pp. 66 and 67, for such a fault in the Hurd mine. Other cases can be cited.

of where it crosses the New York, Susquehanna and Western railroad, another line of graphite rock begins. This has been continuously traced northeast for seven miles. It has not been sought for along Ringwood creek, but it is probably to be found there. In order to explain these two outcrops of exactly similar rock, one is compelled either to assert that the beds are repeated by faulting, or that there are two independent beds, the one dipping under the other. As a proof of the correctness of the first alternative, a rock in every respect similar to the Mount Hope rock is found one mile west of hill 833, and east of Wanaque river. This line of rock has been traced to a point just east of Negro pond or Lake Patoque, as it is now called.

The probability that this rock is the same as the Mount Hope rock is strengthened by two facts: First, the Kanouse, Butler and Sloat mines have been opened on the strike. Second, there is a line of attraction which follows this rock to the New York State line. This line of attraction was run by Mr. Sebenius, M.E.

There can be no doubt that these two beds were originally one, and that they are separated by a line of fault.

TYPE ROCKS OF THE ARCHÆAN AND THEIR DISTRIBUTION.

A systematic attempt has been made during the summer to discover some orderly succession of rocks, or groups of rocks, which will hold true for the whole of the Archæan field. The result has been the selection of four types.

These types are not to be taken in any sense as dividing the Archæan into groups. It is believed that the rocks selected are so constant in their general appearance, in their mineral composition and associations with other rocks, that they can be exactly recognized and located even in widely-separated areas. Having firmly fixed these points, work can then be extended to other rocks with less marked characteristics, and thus more difficult to study.

The selected rocks have not been as yet identified with other rocks, and for the time provisional names have been given them, which can be dropped when they have been either properly identified or described. The name given is the name of the locality in which the rock prominently occurs.

Type I. Mount Hope.

Country Rock of the Mount Hope Iron Mines.

This is in part the feldspathic gneiss of Professor Smock, and in part the hornblende gneiss of Dr. Britton. The rock is usually well foliated.* The foliations are often obscure on a fresh, unweathered surface.

This rock is often interstratified with bands of a hornblende-feldspar rock, which is quartz-free. These bands vary in width from a few inches to many feet. Bedding* is present in the Mount Hope rock, but the beds are very thick.

The rock consists essentially of quartz, feldspar (orthoclase and plagioclase) and magnetite. The magnetite is sometimes largely replaced by hornblende and scattering flakes of biotite. The magnetite occasionally occurs in octahedral crystals, though it is usually in rough, irregular granules. The quartz occurs generally in rounded grains, shot-like in appearance, which look as if they had been pressed into the cleavage face of the feldspars. The texture varies from massive to coarse and to fine-grained and beautifully-foliated.

Type II. Oxford Type.

This rock typically occurs in the Van Nest Gap tunnel of the Delaware, Lackawanna and Western railroad, at Oxford Furnace. This rock is in part, probably, the syenite gneiss of Professor Smock, and the hornblende gneiss, in part, of Dr. Britton. Almost without exception, it appears well foliated, even in fresh fractures of unweathered rock. It usually occurs very free from mixtures of other rocks within its own mass, save, of course, eruptive rocks. It is heavily bedded, but not as heavily bedded as Mount Hope rock.

Essentially the rock consists of two kinds of feldspar and of hornblende, with grains of quartz. Magnetite occurs in varying quantities, but the proportion is always small. Though biotite, in places, takes the place of hornblende almost wholly, yet the rock is, as a rule, very free from this mineral.

The magnetite is sometimes found in octahedral crystals.

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* The terms "bedding" and "foliated" are used in this report in a structural sense alone, unless otherwise stated. No reference is made to sedimentation, in their use.

The quartz frequently occurs in rounded grains, imbedded in the feldspar. It is not often sharply angular.

This, in some localities, is coarse, almost massive, but the foliation is not wholly obliterated. The hornblende is usually distributed in strings, giving the rock a striped appearance. The longer axes of the feldspar are often oblique to the line of foliation.

Type III. Franklin Type.

Occurs at Franklin Furnace in the Ledges between the Hotel and Mine Hill.

This rock is not correlated with the two authors quoted. It is probably mentioned as a biotite gneiss.

The foliation in this rock is not as distinct as in the others. It is more uneven in texture, and the crystals of biotite and other minerals have their larger axes at angles to each other. The "augen structure" is characteristic. "Eyes" both of quartz and of feldspar or of the two minerals mixed, are frequent.

The rocks are rather thin bedded and are frequently interstratified with biotite and hornblende schists.

The essential minerals are quartz, orthoclase, plagioclase rare, and biotite.

Particular emphasis is laid upon the fact that in rocks of this type the quartz and feldspar are usually in sharply-angular grains, thus presenting a striking contrast to the other rock types.

Type IV. Montville Type.

This type of the white or crystalline limestone is given under the head of Archæan only provisionally. It has not yet been proved to be of Archæan age, and there are, apparently, many reasons why it should be considered to be of more recent origin. There is even greater reason for supposing that, even if a part of the rock proves to be Archæan, all will not prove to be so. Enough work in stratigraphy has not yet been done either to affirm or to disprove the assumption that these rocks are of cotemporaneous origin. It is hoped that facts will be collected during the progress of the survey which will set this question at rest. No further description of this rock is needed, beyond saying that it is a white, crystalline limestone of varying degrees of purity. The general appearance of

the rock, as well as the associated minerals, is that which any highly metamorphosed limestone would assume.

The peculiar characteristics of each locality are given in the following paragraphs. The localities at Montville, Wanaque, Pequest Furnace, Jenny Jump mountain, Oxford Church and Mendham agree very closely. In these are great quantitities of serpentine and more or less chrysotile. Diopside is also present. Muscovite is present in small crystals at the localities at Montville and Wanaque. Tourmalines have never been found. The limestone is of a rather bluish gray, rarely white in color.

The Wallkill valley and Vernon valley limestones are, on the other hand, usually sparkling white in color, except where the color is modified by numerous mineral inclusions. The constant minerals are graphite, tremolite, tourmalines and pyrite. In these limestones also appear the great deposits of zinc. The limestones of the localities given above closely resemble those at Wright's pond, Roseville, Tar Hill and Andover mines at Andover and the locality near Oxford Furnace. It will thus be seen that the crystalline limestones on the northwest and southeast side of the Archæan are separated by the following characteristics:

First. The limestones of the southeast (Montville and others) are of a dirty white, lack graphite and tourmaline.

The limestones of the northwest are white in color, and lack, generally, serpentine and muscovite.

Second. The limestones of the northwest are intimately associated, with few exceptions, with iron and zinc ores; while the limestones of the southeast are free from these ores.

As regards the distribution of these rock types thus given, the question is much more easily discussed than the one relating to their thicknesses or the exact order of superposition. In some localities the order seems to be ideally perfect and in the order given.* In other places, equally accessible, the question is not so certainly answered. There are good reasons why this should be so. No actual contacts between the different groups have been found. Even in the case of the Montville and Franklin types, occurring as intimately associated as they do at Franklin Furnace, no contacts are noticed. At Oxford Furnace the Delaware, Lackawanna and Western railroad tunnel through Van Nest gap shows the Oxford type of rock beauti-

* Mount Hope, Oxford, Franklin, Montville.

fully in all its various phases. Yet, though the Straley, Carwheel, Lanning, Harrison and other mines occur in typical Mount Hope rock, and but shortly removed from this place, no contacts were found. Nor did the Oxford rock change gradually. On account of being below the glacial line few good ledges were found, but boulders of disintegration would show plainly one type of rock, and only a few feet away a radical change would be observed.

The most that can certainly be said, then, with respect to these two rocks, is this: the Oxford rock, when found, is almost invariably on the flanks of the hills. Rarely does it form the axial or crest line. It is also principally found flanking the Archæan belt as a whole.

There are notable exceptions to this last statement, as on Ramapo mountain near Pompton. Here, north of the New York, Susquehanna and Western railroad, the Oxford rock appears typically present and then disappears under the more recent formations.

If one bears in mind the general shape of the Archæan outcrops, a more definite idea of the relative distribution of these rocks can be obtained. On the New York border the rocks are about twenty miles across. From this line they stretch in a southwesterly direction across the State towards the Delaware river. They do not present, however, an unbroken series. About half way across the New York border, in the vicinity of Greenwood lake, the Green Pond mountains stretching southwest divide the Archæan into two nearly equal belts.

One of these belts, the southeastern, extends only to within fifteen miles of the Delaware, ending at High Bridge. The northwestern belt, excepting Pochuck mountain, reaches the Delaware in three distinct tongues. Two tongues of rock, Jenny Jump mountain and the Pimple hills, cut off by intruding limestone from the main body of the Archæan, reach towards the northwest.

The three tongues reaching southwest are Musconetcong, Pohatcong, Scott's and Marble mountains. The last two mountains form one tongue. Neither Musconetcong nor Pohatcong mountain has been studied. A section across Musconetcong mountain along the line of the Central Railroad of New Jersey has, however, been studied and will be referred to later.

Another fact worthy of notice is the plateau-like form of the northwestern belt of the Archæan. Beginning at the extreme northwest, the plateau of which Wawayanda lake is the center has the

highest points in the Highlands of New Jersey. These points are near the Williams mine, and are 1,496, 1,437 and 1,456 feet, respectively. As the level of the lake is 1,133 feet, it will readily be seen that these high points are no more than from one to four hundred feet above the general level of the valleys. Southwest of this lies the plateau on which is situated Lake Hopatcong. These plateaus are separated by a fault noticed along the line of the Pequannock river and extending through the notch occupied by the New York, Susquehanna and Western railroad. In this plateau the level of the lake is 926, and the highest point does not reach 1,350 feet. Here, again, the mountains do not reach 400 feet above the general level represented by the lake. The general level of the plateau of Schooley's mountain, as represented by Budd's lake, is seven feet higher than Lake Hopatcong. The general level of the country, however, would be much lower, since the mountains surrounding this lake are rarely 1,200 feet, usually less than 1,100. The last of the plateaus is Scott's mountain, at the southwestern extremity of the Archæan. This plateau, although it has no point reaching 1,300 feet, has a high average level. Taking the Wawayanda, Hopatcong and Schooley's mountain plateaus as one, a peculiar fact becomes noticeable. That is, from the northeast to the southwest the points of elevation represent a tolerably regular descending scale. The highest point, near Wawayanda, is 1,496 feet. The lowest, near Clinton, varies from 550 to 950 feet.

Supposing these points to be leveled, thus filling the valleys to a common plane, this plane, while independent of the dip or pitch of its component rocks, would pitch to the southwest with a decided southeast dip. The plateau on Scott's mountain, on the other hand, would represent a kind of compound structure. The highest points lie in the vicinity of Montana and the plane of the hills, leveled as before, would pitch northeast and southwest from this northwest-southeast axis, while both planes would dip southeast.

This peculiar structure of the Archæan Highlands, as a whole, has not yet been sufficiently studied to warrant any interpretation being put upon it. Yet, several apparently allied facts suggest themselves. On the New York State border, Pochuck mountain reaches an altitude of 1,178 feet. Near Hamburgh the height is 978 feet. At this place (Hamburgh) the Archæan falls under the Silurian limestones. Southwest of Ogdensburgh, in the Pimple hills, the highest point is

1,124 feet. This range of hills descends to the northeast, when at Franklin Furnace the Archæan disappears under the Silurian limestones again. Between the zinc mines at Ogdensburgh (Stirling Hill) and the zinc mines at Franklin Furnace, there appears to be a fault, the zinc ore nor any signs of it appearing between these two places. The probability of a fault along the Pequannock river has already been shown, page 25 of this report. At Oxford Furnace, the lowest point in the dip of the northeast plane from Montana, the strike of the rocks, as indicated by iron mines and by rock outcrops, is nearly east and west. Mount Mohepinoke and the extreme northeast point of Scott's mountain are separated by the Pequest river. Limestone of Silurian age also separates Scott's mountain from Jenny Jump mountain, as in the case of the Pimple hills and Pochuck mountain. Many other facts of this nature could be correlated which are, even without inferences, of striking interest. Some of these facts were noted in the report on the red sandstones* in the report of 1888, and are referred to in the present report.

Referring again to the subject introduced on page 32, let us see how the rock types are arranged on these plateaus. A compact statement, generally true, would be: the typical Mount Hope rocks lie on the summits of the hills, while the Oxford rocks flank them. This, however, is not invariably the case.

The Mount Hope rocks may be separated into three classes: 1st. When the dark mineral is magnetite. 2d. When the dark mineral is hornblende or biotite, or both. 3d. When these minerals are almost wholly wanting, leaving the rock simply quartz and feldspar, texture and general appearance remaining about the same. A dark diorite† rock is oftentimes interstratified with any of the foregoing, iron ore occurring in each of them. In general, then, it may be stated that the whole of the plateau of Scott's mountain consists of these rocks, the flanks of the mountain through which the Delaware, Lackawanna and Western railroad tunnel pierces at Oxford Furnace, and Mount No More, near Oxford Furnace, being apparent exceptions. The black diorite rock is often the only outcrop observable, but removed, at no great distance from it, the Mount Hope rock is

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* See Annual Report State Geologist, 1888; "Red Sandstones of New Jersey."

† This word is used for want of a better one. As used here, it in no respect resembles the eruptive rock of this name, except that it consists almost wholly of feldspar and hornblende.

found. If, however, we make a more minute study of the rocks, another peculiar fact is revealed. Recalling class No. 1 of the Mount Hope rock, when the dark mineral is chiefly magnetite, we find that from a cut on the Belvidere Division of the Pennsylvania railroad, on the Delaware river, two miles below Harmony, this rock typically occurs.

Coming from the cut on the railroad the rock is much fresher than the samples collected from the mountains; yet, on account of the texture, the presence of magnetite and the peculiar poicilitic* appearance of the quartz and feldspar, the rock is not to be mistaken. From this point, which is the lower extremity of Marble mountain, to within a mile of Oxford Furnace, this range of hills was crossed eleven times. From eight of these sections specimens were collected and are now in the laboratory. These specimens establish beyond a doubt, what was conjectured in the field, that the entire length of the central axis of these hills is of the same type of rock. As has been mentioned, there is a break at Oxford Furnace, the rock striking nearly east and west. Beginning at the mines at the furnace, and again going southwest across the Montana plateau, the class of rock changes to No. 2, or a rock in which a greenish mica (partially-decomposed biotite?) and hornblende replace a part of the magnetite. This rock continues, interbedded with the diorite rock, to where the Lopatcong creek turns and flows south across the lower end of the plateau. This distinction between the two classes of rocks is far from being prominently noticeable in the field, but a careful comparison in the laboratory establishes the difference beyond a doubt. No mines of importance have been opened in this belt of rocks, though frequent openings indicate that lines of attraction exist. There are two mica mines opened, but neither is worked. They are peculiar and will receive attention in subsequent reports. On Jenny Jump mountain, Mount Hope rock No. 1 does not appear at all. The central axis of the mountain consists wholly of class No. 2. In these rocks magnetite is very scarce. The nearest approach to class No. 1 is west of the Kishpaugh mines and east of hill 1,004, one mile southeast of Hope. Continuing northeast, this rock disappears

*This term is here used to denote the peculiar "spotted" appearance of the rounded quartz grains in the cleavage surfaces of the feldspar. In this sense it is very much more appropriate than the term "luster mottling" proposed by Pumpelly. The structure here is only discernible by the aid of a pocket lens.

under the white limestone near Southtown, and this in turn under the blue or Silurian limestone.

The Oxford type of rock occurs on the northwest flank of Mount No More, one and a half miles directly west of Oxford Furnace. One mile to the northwest of this occurs again a bed of white limestone. To the east of Oxford Furnace, at Van Nest Gap tunnel, is a beautiful series of this rock, which apparently, at least, overlies the Mount Hope rock. On Jenny Jump mountain, hill 1,004, one mile southwest of Hope, has this rock in a long and broad outcrop. In this part of the Archæan field, a worker labors under one great disadvantage which is not wholly compensated for by one obvious advantage. The field lies wholly south of the glacial action, and as a consequence the rocks are rotted to a great depth. Very few ledges, properly, are found, and on these the rock is so decayed that little else but its structure can be determined. More often than not, sole reliance must be placed upon boulders of disintegration which lie scattered about. In the absence of deep railway cuts or mines, the relative positions of the different classes of rock is a matter of conjecture, for merely local causes, such as tilling of the land, would displace a narrow belt of rocks, which would otherwise indicate at least the strike. There is, however, the great advantage of knowing that the contour of the country, as a whole, is practically unmodified, and that detached rocks, wherever found, are pretty sure indices of the nature of the underlying strata. Going northwest from this point (Jenny Jump and Scott's mountains), Upper Pohatcong and Allamuchy mountains received little personal attention, save a section along the line of the Sussex railroad, from Andover to Waterloo. This section showed rather heavy beds of the Oxford type on the northwest flank; but on the extreme northwest, near Andover, rocks of the Franklin type were more simulated, though not certainly identified. In the center of this section, near Waterloo, rocks appeared which look like the Mount Hope type, class No. 2.

Mr. Van Horn, who assisted me a part of the summer, collected specimens to the northeast of Andover. These specimens seem to show that the above conclusions are correct, viz., that the Montville, Franklin and Oxford are represented on the northwest flank, and that only the mica-hornblende type of the Mount Hope rock appears in this section. A prevalent northwest dip, persistent for a comparatively large area, explains this. That is, if the hypothesis be true that the Green

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Still farther to the northeast the Pimple hills were examined. These hills showed the customary axial outcrop of Mount Hope rock, in this case No. 1. The Oxford rock was not observed. The fact that by far the greater part of these hills are covered by glacial drift will, no doubt, explain this. Even the Franklin and Montville types, which are here, evidently are not at all conspicuous, owing to this cause.

Taking up next the great plateaus, Wawayanda, Hopatcong and Schooley's mountain, we find again that the great lines of axial rock is almost wholly Mount Hope. This is not only true, but it is evident that class No. 1 is the dominant rock. It must be borne in mind that, on this central plateau, are also interstratified beds, if we may call them such, of hornblende or mica diorite, which are almost wholly free, in most places, of magnetite. On this plateau it is also to be noted that beds of iron ore, some very extensive, as the Hurd, Weldon, Schofield, Ogden, &c., occur, and that these beds partake of the structural peculiarities of the enclosing rock. Another fact to be noticed is the texture of the greater part of the rocks. This is in striking contrast to the rocks of the same type which are found on the outlying or flanking ranges of hills. Instead of being, in general, fine grained and thinly and evenly foliated, the texture is very coarse, at times so coarse as to wholly obliterate all traces of foliation, save on weathered surfaces. On these surfaces the feldspars, whitening, show a distinct foliation or parallel arrangement of the mineral constituents. The magnetite crystals are not so often in octahedral crystals, but are jagged in outline and appear as if pressed into the minutest crevices. The globular or semi-globular form is not so frequently observed.

The same is true of the quartz. This often has the same jagged outlines, but microscopic sections show rounded globules which appear to have been either pressed into the feldspar crystals or the feldspar to have grown around them. Around these included globules the feldspar is wholly undisturbed, the thin twining bands running nearly up to and disappearing suddenly at the border of the enclosed quartz. The accessory mineral, zircon, appears in larger, almost macroscopic (quite so in and near the iron mines) crystals, though not very abundant. Yet, with all these differences, if one can use so

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Near the High Ledge mine, west of Kenville, the country appears to have been greatly disturbed. The rocks are dislocated, and the coarse zircon rock, bearing iron ore, comes to the surface. In fact, the High Ledge mine is opened in this rock. Besides this there are numerous dikes of trap which have made their way to the surface. On the northeast side of the Delaware, Lackawanna and Western railroad this line of rock is again resumed, and passing through in the line of the Gove mine again appears near the Hurd mine at Hurdtown. The country between these points has not been explored.

From the Hurd mine this line of coarse rock leaves the more direct trend northeast and changes to a nearly north and south line. The line of the Ogden Mine railroad follows this almost exactly. This rock has not been found northeast of hill 1,307, about three miles north-northeast of the Ogden mines, and south of the New York, Susquehanna and Western railroad. The interval between these two places is occupied principally by a very white rock, consisting principally of feldspar and quartz. In places the feldspar has changed to epidote, and small fractures in the rock are filled with small crystals of this mineral. The rock is massive and appears to have included slabs and angular fragments of foliated rocks included in its mass. There is not much doubt of its eruptive nature.

Northwest of the New York, Susquehanna and Western railroad, for a short distance, this same eruptive rock occurs, and near a log school-house two miles northwest of Stockholm, these included fragments can plainly be seen.

On hill 1,161, two miles east of Franklin Furnace, this coarse rock

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The same rock is again encountered on the Vernon road about three miles southeast of Vernon. Here it is on the highest part of the mountain and seems to strike northeast as usual. The country has not been traversed north of this to the New York State line, but from the mine openings which have been made it is presumed that the same rock continues.

Beginning at Lower Longwood, on the mountain outlying to the east of hill 1,199, the Mount Hope type of rock again occurs. This is almost directly east of the Hurd mine. The same rock outcrops on the Weldon mine road where it is intersected by the Hurdtown road. The writer is not at present able to state whether or not this rock occupies the main part of Bowling Green mountain towards Milton. This mountain is yet to be surveyed.

Between this point, which is near hill 1,222, and the Hurd mine the country to the north is rather swampy and to the south deeply covered with drift. It is thus impossible to state as to the nature of the rocks for the greater part of this surface. It may be well to state, however, that rocks bearing a great quantity of graphite were found near an old wood-road half way between points 1,141 and 1,196, west of Lower Longwood. Nothing is yet certainly known of the position of these graphite gneisses relative to the other rocks, save that they appear to be above the magnetite gneisses or Mount Hope type of rock.

At the mine near point 1,318, on the road from the Schofield mine to Milton, the Mount Hope rock No. 1 is found and continues east of Holland to the Pequannock river.

From hill 1,190, west of Wallace Corner, however, a wholly massive rock appears which is probably eruptive in its nature. This, with the Pequannock river, seems to separate this belt of rock from Dunker mountain, which is again the Mount Hope rock. Corresponding to these erupted rocks on the south side of the river, there is, on the north side, a large pass through which the New York, Susquehanna and Western railroad cuts. This rock is greatly disturbed and numerous dikes are thrust up through the fissures.

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What is true of the Hopatcong plateau is also true of the Wawayanda area. This is so covered with drift, generally, that whole square miles are without indication of the underlying rock. The hills, however, are usually beautifully exposed. From the apparently conflicting testimony of the dips on these hills, though, little can be gained which would warrant one in extending any given rock for a great distance into the drift-covered valleys.

Occasional minor ridges, however, seem to indicate that the rocks in the valleys are of a different nature from those on the flanks and crests of the hills. For instance, one mile directly south of Canistear the graphite gneiss, which has been formerly mentioned, appears in the road. They appear to strike a little west of north with a very flat dip. This corresponds closely with the rocks between this point and Stockholm.

A little northwest of hill 1,242, west of Canistear, the same graphite gneiss appears in a very extended outcrop on the farm of S. F. Card. A small prospect hole has been opened in the search for workable deposits of graphite.

Returning for a moment to the Hopatcong plateau, let us look at the west shore of the lake. The Stanhope mines are located on hill 946, one-half mile north of Musconetcong river, and one mile northwest of Stanhope. The country rock of this mine is the Mount Hope type No. 1.

From this point northwest to Bear ponds, a broad belt of this rock, about two miles in width, has been surveyed. The only exception to the prevailing Mount Hope type is the diorite rock, mentioned as being found associated with it. The usual accompaniment of iron ore in this rock is fully testified to by numerous openings made by prospectors in their search for it. Biotite rocks are occasionally met with, but they are usually associated more or less intimately with the diorite rock.

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The rocks within the above-designated area do not appear to have been violently disturbed, as they lie with considerable degree of regularity. Several thin dikes of trap, though, are noted in the roadway that passes between the lake and Fred. Mast's hotel.

A disturbance has evidently taken place between Waterloo and Stanhope, and so on through Drakesville, Port Oram, Dover, Rockaway and Boonton, the last four places mentioned being on the line of the Rockaway river. This fault line has already been referred to. The special proof of it here is the fact that the rock at the Delaware, Lackawanna and Western railroad station at Waterloo is of the Oxford type, while, as has been mentioned, the rock north of the Musconetcong river is of the Mount Hope type No. 1.

Between Bear ponds and the road leading from Woodport to Sparta, no work has been done. One mile and a half northwest of Woodport, however, the Mount Hope rock No. 1 comes in, and has been traced to the southern point of hill 1,314, one-fourth of a mile west of the Ogden mine. Northeast of this point it appears to join the country rock of the Ogden mines. From the foregoing description it will be seen that the principal rocks on this broad belt or plateau, reaching from the New York State line to the Delaware river, consist of the Mount Hope type. This, however, does not certainly include the territory south of Central Railroad of New Jersey, between Junction and High Bridge, to the Delaware river. This country has not yet been surveyed and nothing can be said of it. It has already been suggested (see page 32, foot-note) that the Oxford type of rock came above the Mount Hope in geological sequence. Though nothing certainly confirming this opinion can as yet be advanced, yet there are a few additional facts which are to be noted. For a considerable distance below Waterloo station the rock which outcrops there continues. This rock is, without doubt, of the Oxford type. One and a half miles below and near the 900-foot contour, the Mount Hope rock occurs, and extends across its strike to the east. Going northeast from this point, the Oxford rock is not again found till after crossing the New York, Susquehanna and Western railroad, near Two Bridges. On a section line run from Stockholm to Hardistonville, the rock was found flanking hill 1,137, two miles east of Hardistonville. This hill appears to be an anticline, the rocks, though steeply inclined, dipping southeast and northwest, respectively.

About one and one-fourth miles east of McAfee, on the west slope of Hamburgh mountain and of hill 1,414, the Oxford rock is again found. It dips northwest here. It was not found to the east of this point. Neither was the rock found between Vernon and Wawayanda.

If topographic sheet No. 4, Atlas of New Jersey, be referred to, it will be noted that, from Two Bridges to Vernon, Hamburgh mountain is wholly separated from Wawayanda mountain and lies to the west of it. East of Hardistonville there is a decided anticline, and this probably extends from this point to the northeast point of the mountain. As has already been noted, on hill 1,164, east of Franklin Furnace, there is a typical outcrop of Mount Hope rock. This has been actually traced from this point to near the road from Hardistonville to Stockholm. On the crest of the anticline this same rock was also found. Apparently the same line of rock was intercepted on the road over Hamburgh mountain from McAfee, where a wood-road from the hematite mine near Rudeville enters it. Hamburgh mountain, therefore, appears to be an anticline, with a central axis of Mount Hope rock, which is flanked by the Oxford type of rock. On this mountain, so far as can be ascertained, there is no rock of a different type between the Mount Hope and the Oxford.

A careful study of this plateau may reveal yet other data upon which to found more strongly this supposition, but at present no other occurrence of the Oxford rock is known.

We come now to the southeastern division of the Archæan Highlands. This division or belt forms the Ramapo and the Passaic belts* described by Dr. Cook. This part of the Archæan is almost wholly severed from the Wawayanda and Hopatcong plateaus by the Green Pond range of mountains, reaching from the New York State line to near Port Oram; from Port Oram, through the Plains of Succasunna to German valley, and from there, through German valley to High Bridge. Though the whole of this belt has not been carefully surveyed, enough has been done to demonstrate that rock distribution is quite different from that on the Central Highland belt.

Instead of a general plateau-like appearance, the hills are more irregular, and they rise to greater comparative heights above the surrounding levels. The same rock does not usually hold for great distances in either length or breadth. There are two marked exceptions to this statement—the long range of iron ore reaching from Chester

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To the west of this line lie the Canistear, Wawayanda and Green mines in the same rock. To the east lie the rocks of the Green Pond series.

What is true of the Hopatcong plateau is also true of the Wawayanda area. This is so covered with drift, generally, that whole square miles are without indication of the underlying rock. The hills, however, are usually beautifully exposed. From the apparently conflicting testimony of the dips on these hills, though, little can be gained which would warrant one in extending any given rock for a great distance into the drift-covered valleys.

Occasional minor ridges, however, seem to indicate that the rocks in the valleys are of a different nature from those on the flanks and crests of the hills. For instance, one mile directly south of Canistear the graphite gneiss, which has been formerly mentioned, appears in the road. They appear to strike a little west of north with a very flat dip. This corresponds closely with the rocks between this point and Stockholm.

A little northwest of hill 1,242, west of Canistear, the same graphite gneiss appears in a very extended outcrop on the farm of S. F. Card. A small prospect hole has been opened in the search for workable deposits of graphite.

Returning for a moment to the Hopatcong plateau, let us look at the west shore of the lake. The Stanhope mines are located on hill 946, one-half mile north of Musconetcong river, and one mile northwest of Stanhope. The country rock of this mine is the Mount Hope type No. 1.

From this point northwest to Bear ponds, a broad belt of this rock, about two miles in width, has been surveyed. The only exception to the prevailing Mount Hope type is the diorite rock, mentioned as being found associated with it. The usual accompaniment of iron ore in this rock is fully testified to by numerous openings made by prospectors in their search for it. Biotite rocks are occasionally met with, but they are usually associated more or less intimately with the diorite rock.

The rocks within the above-designated area do not appear to have been violently disturbed, as they lie with considerable degree of regularity. Several thin dikes of trap, though, are noted in the roadway that passes between the lake and Fred. Mast's hotel.

A disturbance has evidently taken place between Waterloo and Stanhope, and so on through Drakesville, Port Oram, Dover, Rockaway and Boonton, the last four places mentioned being on the line of the Rockaway river. This fault line has already been referred to. The special proof of it here is the fact that the rock at the Delaware, Lackawanna and Western railroad station at Waterloo is of the Oxford type, while, as has been mentioned, the rock north of the Musconetcong river is of the Mount Hope type No. 1.

Between Bear ponds and the road leading from Woodport to Sparta, no work has been done. One mile and a half northwest of Woodport, however, the Mount Hope rock No. 1 comes in, and has been traced to the southern point of hill 1,314, one-fourth of a mile west of the Ogden mine. Northeast of this point it appears to join the country rock of the Ogden mines. From the foregoing description it will be seen that the principal rocks on this broad belt or plateau, reaching from the New York State line to the Delaware river, consist of the Mount Hope type. This, however, does not certainly include the territory south of Central Railroad of New Jersey, between Junction and High Bridge, to the Delaware river. This country has not yet been surveyed and nothing can be said of it. It has already been suggested (see page 32, foot-note) that the Oxford type of rock came above the Mount Hope in geological sequence. Though nothing certainly confirming this opinion can as yet be advanced, yet there are a few additional facts which are to be noted. For a considerable distance below Waterloo station the rock which outcrops there continues. This rock is, without doubt, of the Oxford type. One and a half miles below and near the 900-foot contour, the Mount Hope rock occurs, and extends across its strike to the east. Going northeast from this point, the Oxford rock is not again found till after crossing the New York, Susquehanna and Western railroad, near Two Bridges. On a section line run from Stockholm to Hardistonville, the rock was found flanking hill 1,137, two miles east of Hardistonville. This hill appears to be an anticline, the rocks, though steeply inclined, dipping southeast and northwest, respectively.

About one and one-fourth miles east of McAfee, on the west slope of Hamburgh mountain and of hill 1,414, the Oxford rock is again found. It dips northwest here. It was not found to the east of this point. Neither was the rock found between Vernon and Wawayanda.

If topographic sheet No. 4, Atlas of New Jersey, be referred to, it will be noted that, from Two Bridges to Vernon, Hamburgh mountain is wholly separated from Wawayanda mountain and lies to the west of it. East of Hardistonville there is a decided anticline, and this probably extends from this point to the northeast point of the mountain. As has already been noted, on hill 1,164, east of Franklin Furnace, there is a typical outcrop of Mount Hope rock. This has been actually traced from this point to near the road from Hardistonville to Stockholm. On the crest of the anticline this same rock was also found. Apparently the same line of rock was intercepted on the road over Hamburgh mountain from McAfee, where a wood-road from the hematite mine near Rudeville enters it. Hamburgh mountain, therefore, appears to be an anticline, with a central axis of Mount Hope rock, which is flanked by the Oxford type of rock. On this mountain, so far as can be ascertained, there is no rock of a different type between the Mount Hope and the Oxford.

A careful study of this plateau may reveal yet other data upon which to found more strongly this supposition, but at present no other occurrence of the Oxford rock is known.

We come now to the southeastern division of the Archæan Highlands. This division or belt forms the Ramapo and the Passaic belts* described by Dr. Cook. This part of the Archæan is almost wholly severed from the Wawayanda and Hopatcong plateaus by the Green Pond range of mountains, reaching from the New York State line to near Port Oram; from Port Oram, through the Plains of Succasunna to German valley, and from there, through German valley to High Bridge. Though the whole of this belt has not been carefully surveyed, enough has been done to demonstrate that rock distribution is quite different from that on the Central Highland belt.

Instead of a general plateau-like appearance, the hills are more irregular, and they rise to greater comparative heights above the surrounding levels. The same rock does not usually hold for great distances in either length or breadth. There are two marked exceptions to this statement—the long range of iron ore reaching from Chester

*See Annual Report State Geologist, for 1868, p. 44. Also subsequent reports.

to near Green Pond, and the long line of graphite gneiss which runs nearly parallel to it. Beginning at the extreme southwest of this belt, the rocks appear to be distributed in the following manner: From High Bridge to Lebanon, on the Central Railroad of New Jersey, the rocks are badly decomposed. Mount Hope No. 1 was not once encountered. Near Annandale, however, a rock consisting almost wholly of feldspar and quartz was found. The feldspar is of two kinds; the quartz has the rounded, granular appearance perfectly developed. This rock is accompanied by a kind of diorite rock, which appears to be the more abundant. This rock seems to be Mount Hope No. 3.

The country between this point and the Chester iron mines has not been explored; but a line northeast from this point would pass to the east of the mines at Chester. This, taken in connection with the accompanying diorite rock, leads to the assumption that this outcrop is the continuation of the Chester iron ore outcrop. It will, of course, be remembered in this connection that in the Central Highland or plateau region this diorite rock is usually found intimately associated with the Mount Hope rock.*

At Ferro Monte the country rock, when found, was carefully studied. It has, as usual with Mount Hope No. 1, two kinds of feldspar. The quartz is in rounded, sub-angular grains; the magnetite sometimes in crystals, but more usually in grains more or less angular. The whole rock is distinctly and evenly foliated. At Mine Hill, Port Oram, in the road just north of Rockaway river and south of Spicertown, this same rock is found. A section line over the Mount Hope range, one mile north of the mines, still showed the same rock. This same rock is also found on the road from Hibernia to Lake Denmark direct, and also on a road which goes to Denmark three miles north of this last road.

At Marcella, five miles from Denmark, a poor but characteristic outcrop was again found. From this point the rock was traced almost continuously to the Howell mine, on Copperas mountain.

Near Lake Denmark several mine openings have been made within this line of rock. Though no great body of ore has been struck, the mine openings are of great importance in showing a continuity of the iron ore, even if not in quantity enough to pay for working. The openings from Denmark to Marcella are also of importance, as show-

*See page 32 of this report.

ing the same thing. A branch of the Morris County railroad runs from the Morris County railroad, near Denmark, to the north end of the Hibernia mines. Several cuts along this road pass through Mount Hope rock No. 1. It is, therefore, regarded as all but positively demonstrated that the line of iron-ore beds from the Bryant mine, below Ferro Monte, to and including the Howell and Green Pond mines, on Copperas mountain, belong to the same great bed or deposit.

From hill 901, just across the Rockaway river from Dover to Split Rock pond, the rock seems to be of a somewhat variable nature. The mineral constituents still remain quartz, feldspar and magnetite, but the proportion of magnetite is exceedingly variable. At the point just mentioned, and in the quarries of the Delaware, Lackawanna and Western railroad, at Dover, the percentage of magnetite is very small.

A little west of Swede's mine the rock is very rotten, almost completely decomposed, and magnetite is almost wholly absent. Following along this line by the White Meadow mines, Mount Hope No. 1 is unmistakably found.

On the immediate southwest side of Hibernia brook, at Lower Hibernia, the magnetite is almost wholly replaced by a greenish mica. The same rock holds for a considerable distance west of the Hibernia mines. At the northern point of the mines, where the branch of the Morris County railroad comes in, the rock again gradually changes to Mount Hope No. 1, and holds its own to near Split Rock pond.

Here the rocks are much disturbed, the dip and strike change, and the Mount Hope rock is not again found to the northeast of this point. The mountain just west of the pond, however, has not been examined.

A line of undoubted Mount Hope rock No. 1 runs from the Swede's mine, east of Dover, to a point a little northwest of Cobb's mine, east of Split Rock pond.

At Rockaway station, Delaware, Lackawanna and Western railroad, Mount Hope No 2 is found in the railroad cutting. This line of rock runs one mile west of hill 903, northeast of Rockaway. From this point the outcrop is continuous to a point in the road west of hill 611. The rock is found on hill 1,107, east of Split Rock pond, and ends at hill 1,058, west of Smith Mills, and south of the Peequannock river. From a point just north of hill 641, west of Powerville, another line of Mount Hope rock has been traced to the Rockaway

Valley mines. This line has not been traced farther northeast. It is presumed, however, that it extends certainly as far as Stone House brook. Its exploration immediately southwest of this point is checked by the Rockaway valley, under which the rocks disappear. The last line of this rock begins on hill 815, northeast of Boonton, passes over hill 811 and through the Brook Valley mines. Between this point and the Pequannock river the hills are so covered by drift as to present no outcrop.

The Pompton, Lanagan, De Bow and Ryerson mines appear to be in a third line of this rock, but this point has not been certainly determined. The area just described contains about eighty-four square miles. It is bounded on the north by the New York, Susquehanna and Western railroad from Pompton to Charlottesburgh; from Charlottesburgh to Drakesville, on the northwest, by the Green Pond mountain, and on the southwest by the Delaware, Lackawanna and Western railroad. There are six lines of Mount Hope rock running northeast-southwest, east of Lake Denmark. East of the Morris County railroad a stone quarry has been opened in a ledge. This rock is undoubtedly Oxford type, and is the only known occurrence of this type within this area.

Graphite rocks are, however, rather numerous, and of two kinds. One is a coarse pegmatite-kind of rock, consisting principally of quartz, feldspar (orthoclase), biotite and graphite. The latter mineral is present in large flakes and is mingled generally with the biotite. The biotite sometimes appears to replace the graphite wholly; at others the contrary is true—graphite is present with no biotite. In this coarse rock minute crystals of zircon are observed. Garnets (almandine) of large size are present in varying proportion, but rarely have crystalline faces.

Foliation is present in more than traces.

The other rock is a true graphite gneiss, in which quartz, orthoclase, biotite and graphite occur in varying proportions. In the majority of the specimens collected minute crystals of zircon occur in great abundance. Hornblende is occasionally present. Garnets are not certainly observed. A light-colored pyroxene is usually present in considerable quantities in some localities.

Garnets are almost invariably found in connection with the coarse rock, but not certainly with the graphite gneiss. Save the fine foliation in the graphite gneiss, the occurrence of garnets constitutes the

principal difference in the two rocks. Accompanying the graphite gneiss is a very coarse rhombic pyroxene rock. It presents no traces of foliation, but, on the contrary, has every appearance of being non-foliated eruptive. This rock is not constantly present in the sense of being a parallel bed, but the rock is frequently met with, as it were, pushing up through or from under the graphite gneiss.

There are two known localities where this rock is not found in connection with the graphite gneiss. One is near the Stinson mine, on Jenny Jump mountain; the other is a mica mine east of Lower Harmony. At each of these localities, also, the rock has every appearance of being eruptive. The first of these graphite rocks, the coarse kind, is found less than one-fourth of a mile east of the United States Government quarry, southwest of Lake Denmark. As has been remarked, the quarry rock is Oxford type. Less than one-half of a mile east of the graphite rock is the Mount Hope No. 1 of the Mount Hope ore deposits. The common relations of these rocks at this locality cannot further be determined on account of the poor exposure.

Along the crests of hills 1,026 and 1,030, east of the White Meadow mines, and also in the valley or gorge one-half mile directly south of Lower Hibernia, this coarse graphite rock is again found. Its relations to the surrounding rocks are also equally obscure. On hills 1,026 and 1,030, one-fourth of a mile west of this locality, Mount Hope No. 1 is found. To the east, one-half of one mile, the same type of rock is found. The rock intervening between the graphite rock and the Mount Hope to the east cannot be referred with certainty to any rock type. In the valley south of Lower Hibernia, the rocks east and west are so far removed as to furnish no guide to their relative positions. The greater part of the valley is also wholly covered by drift.

One-eighth of a mile west of Hibernia brook, and near the east foot of hill 939, a rather extended outcrop of graphite gneiss occurs. The gneiss is beautifully foliated. It also has large granular garnets. Otherwise it does not differ from the regular graphite gneiss. The rocks in the immediate vicinity of this outcrop are greatly disturbed. A great boss of coarse granite seems to lie on either side of the gneiss. The gneiss itself dips southeast, northeast and northwest within a short distance. Between the gneiss and the Hibernia mines the rocks have a prevailing northwest dip. Here, as in other places, the drift

obscures the greater part of the country. Just to the west of this graphite gneiss, however, are mines which lie in the Mount Hope line, and the Mount Hope rock No. 1 is the country rock, as usual. It is extremely doubtful if any rock lies between the graphite gneiss and the Mount Hope No. 1 in this direction. To the east, about one mile distant, Mount Hope No. 1 is again found. Two miles and one-half east-northeast of Rockaway station a line of graphite gneiss begins and runs north, 55° east, for a distance of seven miles. It terminates on hill 930, one mile east of Stickle pond. This outcrop is continuous for the whole distance, and has been proved to be so by actually following along the line of outcrop. Mount Hope No. 2 lies one mile to the west. To the east, across Rockaway valley, Mount Hope No. 1 is found.

There is a great deal of pyrite present in this rock, as is usual. There are three other localities of limited area in the field. One is near Bald hill, east of Brook valley. This is in direct line with the old graphite mine at Bloomingdale. The line is not known to be continuous which joins these places, but boulders have been found at intervals which resemble the graphite gneiss in every respect.

On the New York, Susquehanna and Western railroad, north of hill 577, is another small outcrop of the characteristic graphite gneiss. At the last places mentioned the Mount Hope rock has been found at no great distance, both east and west.

Northeast of the New York, Susquehanna and Western railroad the Ramapo mountain and the hills west of the Wanaque river have the same general characteristics as the area just described. The country is rough and hummocky, and much of it is covered by drift. Enough of it is exposed, however, to suggest that the rocks are even more diversified than those of the last-mentioned area. There are few, if any, long, continuous lines of rock with these exceptions. One long line of Mount Hope rock has already been referred to, reaching from near Pompton station, New York, Susquehanna and Western railroad, through the Kanouse, Sloat and Butler mines to Lake Patoque, on the interstate line.

The country rock of some of the Ringwood mines is also of this type, as are the axes of the hills between these mines and Greenwood lake. The relations between the Mount Hope and the Oxford types of rock are excellently illustrated on the Ramapo mountain and on the mountains east of Greenwood lake. Yet, in these places there are

neither contacts nor exposures of rock where one can be traced into the other.

On the east flank of Ramapo mountain from Suffern, N. Y., to three miles below Darlington, the Oxford type of rock is found; in many cases reaching nearly or quite to the summit of the flanking hills. On hill 1,053, and at its southern point 883, southwest of Lake Patoque (Negro pond), is the corresponding bed of Oxford rock on the western flank of the mountain. Both flanks of hill 1,227, between Ringwood and Greenwood lake, southwest from the State line to Hewitt, are also Oxford rock. The axis of this hill is Mount Hope. By far the most extensive exposure of this rock reaches from State Line (New York and Greenwood Lake railroad), along the eastern shore of Greenwood lake to the so-called granite quarry on the New York, Susquehanna and Western railroad, below Charlotteburgh. Along this line the exposure is practically continuous, and the rocks are very heavily bedded. This is especially true in the vicinity of Upper Macopin. In no one of these localities has any trace of a graphite gneiss been found to my knowledge. No contact between the Oxford and Mount Hope types, nor any exposures where one graded into the other, were found. Yet, it is evident they are not widely separated, since the two are found, one flanking and the other forming the axial crests of the same hills. On pages 29 and 32, footnote, of this report it was suggested that there appeared to be an orderly series of the rocks of the Archæan Highlands. If this suggestion is not interpreted too rigidly it can be allowed to remain, and it will be of value as an aid to further study of the Archæan.

For instance, in every known locality where the Oxford type of rock occurs, the Mount Hope type appears not far removed and always *underlying* the first-named rock. Particular attention is again directed to the typical locality at Oxford Furnace tunnel on the Delaware, Lackawanna and Western railroad, on the road from Hardistonville to Stockholm, at Oxford Furnace and the mountains lying east of Greenwood lake. At the quarry southwest of Lake Denmark, however, a graphite gneiss comes, apparently, at least, between the Mount Hope and the Oxford gneiss.

The limestones at Montville and Wanaque, though regarded as being, probably, of the same age as the Franklin Furnace zinc-bearing limestones, yet are very close to the Mount Hope rocks, and no well-recognized type has been found between the two. At

Franklin Furnace the white limestones lie conformably to the Franklin type of gneisses. Yet, a section from hill 720, west of the Furnace pond to hill 807, would give crystalline limestone, on the east Franklin gneiss, crystalline limestone and Mount Hope No. 1. This section would be only one mile in length. It is just to say, however, that by far the greater part of this distance is deeply buried under the drift, and the limestone just to the west of hill 720 is of limited extent. It may be that the Oxford type is wholly covered. A more extended study at Franklin Furnace, by means of a more detailed section line, beginning on Mine hill and going west to the cross roads on the 520-foot contour, would give on the east a bed of crystalline limestone of uncertain thickness, a bed of zinc ore fifteen to thirty-five feet thick, garnetiferous limestone and biotite and feldspar mixed, a bed of iron ore ten to twenty feet, Franklin gneiss of unknown thickness, a wide drift-covered area of three-eighths of a mile, then a small outcrop of Mount Hope rock. A careful study of the iron ore and mine rock shows that this ore-bed differs essentially from the great ore deposits of the Wawayanda and Hopatcong regions and those east of the Green Pond mountains, including, probably, the Ringwood, Kanouse, Butler and Sloat mines.

The country rock (the foot-wall, at least,) is the Franklin gneiss.* The ore in many places consists so largely of limestone as to be practically self-fluxing. Graphite is a common mineral, and occurs both in the admixed limestone and the iron ore. Chlorite† is present in large, well-defined crystals. Allanite is very abundant in the waste rock, and occurs in the customary tabular crystals, being one-fourth to one inch long and one-eighth to one-fourth of an inch thick. Garnet is also found (not in good crystals) on the hanging-wall side. It is not certain that it occurs in the ore proper. The ore also runs much lower in phosphorus than the ores to the southwest—the Mount Hope and Dickerson range. At the Andover and Tar Hill mines white limestone is not far removed from the mines. The iron ore has a considerable amount of limestone, highly crystalline, zinc as a sulphide, graphite and garnet. Other minerals occur, but they are not important for the present purpose. Mount Hope rock is not certainly found in this locality, but to the west a rock much

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* See page 31 of this report.

† No chemical analysis of this mineral has been made. This statement is made on macroscopic characters alone.

resembling the Franklin gneiss is found. The Roseville mines, three miles to the southeast of the Andover mines, are almost exactly similar, save, possibly, the occurrence of sphalerite and galena.

In the intervening country there are several limited areas of crystalline limestone. A section along the Sussex railroad also shows the occurrence of Oxford gneiss. This examination is confirmed by collections made by Mr. Van Horn, in which are rocks of undoubted Oxford type. There is another striking instance of the occurrence of white limestone, zinc and graphite-bearing iron, in close proximity, at the Belvidere Iron Company's mines, one mile northwest of Oxford Furnace. A section from the summit of hill 932, west of Oxford Furnace, through the Belvidere mines to the public road, west of Raub's mine, would give the following rocks: Beginning with hill 932, Mount Hope No. 1, three-eighths of a mile drift-covered; bed of iron ore, carrying much limestone and a little graphite; crystalline limestone, a bed of zinc sulphide. The rocks on the continuation of this line are drift-covered and concealed.

A line of iron mines follows the crystalline limestone on the east to Oxford Church. At this place there are small green tourmalines found in the limestone. In the ravine through which flows Pophandusing creek, and near Marshall mines, there is a kind of ophiolite. It is found abundantly on the east side of the road by an old millrace. At Pequest Furnace is a limited area of ophiolite, plainly shown in the cuts, both of the Delaware, Lackawanna and Western railroad and the Lehigh and Hudson railroad. To the west, but a few rods, are the Pequest mines. It is supposed that these mines belong to the group of mines now being discussed. But between these mines and the Hoit mines, one-half of a mile north, is an extended outcrop of Mount Hope rock. No rock of the Oxford type is here found.

The last example of the occurrence, in close connection, of the white limestone and iron-ore beds, is on the road from Danville to Southtown, at the northeast point of Jenny Jump mountain. On the west side of this road are numerous openings made in search of iron ore. The Stinson mine is about the only one which has been extensively worked. This mine lies *under* the white limestone. At the northeast end of the mountain there are four distinct bands of white limestone, three of which lie east of the road. With the excep-

tion of the first band of limestone, which lies on the western border of the Pequest meadows, each band of limestone has an iron-ore bed dipping southeast under the limestone. At the Howell mine and two others to the west, graphite and limestone were found with the refuse from the mine.

From the greatly-disturbed condition of these rocks, from the re-appearance of the limestones and beds of iron ore all dipping southeast, from the fact that a great eruptive dike of rhombic pyroxene rock comes just west of the Davis mine, and along the strike of the hills, it is inferred that there are northeast-southwest faults. This is strengthened by the finding of an outcrop of Oxford gneiss on the east side of the road, two miles southwest of the road leading to the Stinson mine.

This occurrence can be explained on the ground of faulting along the line of strike and the subsequent erosion of the overlying rock. To recapitulate briefly: the Franklin Furnace mine, Howell's and other mines on Jenny Jump mountain, Pequest, Belvidere Iron Company's mines, Marshall mines at Oxford Church, Andover, Tar Hill and Roseville mines all agree in the following particulars:

First. There is more or less graphite and limestone in their ores.

Second. They are intimately associated with white limestone, under which they lie.

Third. In addition to the last, in four localities zinc ores occur more or less intimately associated with them.

Fourth. They are nowhere directly associated with rocks of the Mount Hope type.

To compare these mines in minute details they would differ among themselves to a considerable extent. But comparing them with the greater iron mines, such as the Ogden, Hurd, Ferro Monte, Mount Hope and Hibernia mines, we find that their individual differences fall to utter insignificance beside the greater points of difference which separate these two belts.*

The more prominent points of difference may be summed up as follows:

First. These latter mines always occur interbedded with the rocks of the Mount Hope type.

Second. They are never found in connection with white limestone deposits.

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* Belts represented by the Franklin Furnace mine and by the Hurd mine.

Third. Graphite and limestone* are never found mingled with their ores.

By comparing the southeastern Archæan, where the Oxford and Mount Hope types more frequently occur, with the northwestern, where the crystalline limestones and associated ores occur more abundantly, the reason for assuming the relative positions of these type rocks, as given on page 32, foot-note, will be readily seen. If it is also remembered that the central belt of Archæan rocks consists very largely of the Mount Hope type, the reason for this sequence will be even more apparent. This sequence is not, however, fully satisfactory. There are localities which apparently contradict each other, while in general, facts appear to point towards the placing the white limestones as the youngest of the series.† This differs from Dr. Britton's classification in the following respects: First, he makes the tremolite and kyanite and graphite schists, tourmaline rock and "impure crystalline limestone" and serpentine, the youngest of his series.

The objection to this is that the kyanite and tremolite schists of Pochuck mountain appear to dip *under* the white limestone at McAfee. The graphite gneisses or schists have been shown to lie near the Mount Hope rock, and probably under the limestones. The limestones are not yet sufficiently known to enable us to assign them to different horizons.

Second, the iron ores are grouped, by Dr. Britton, between his "massive group" and the "gneissic and schistose group." That is, they are associated without distinction with beds of "Franklinite" (presumably the zinc beds at Franklin Furnace and Stirling Hill), "crystalline limestone, dolomite and ophiolite locally containing scattered flakes of graphite."

The objection to this is that, as already shown, the iron-ore beds of the Central Highlands and of the Archæan, southeast of the Green Pond mountains, lie wholly, so far as is known, within rocks of the Mount Hope type, in part the "massive group." That is, the "I. and II." groups, ["The Massive Group" and the "Iron (Magnetite) Bearing Group,"] are not mutually exclusive, but they cut into each other.

* Several instances have come under the writer's notice of graphite's being found in these ore-beds. A blow-pipe test, however, has shown the supposed graphite to be molybdenite. Calcite frequently occurs in *veins*, never as a rock.

† See Annual Report State Geologist, 1886, page 77.

The same is true of groups II. and III., or the "Iron (Magnetite) Bearing Group" and the "Gneissic and Schistose Group."

These facts point most clearly to the extreme difficulty of any classification or division of the Archæan in our present state of knowledge. In order to explain away these difficulties by the prevalent hypothesis of sedimentation, one must clearly prove, in the first place, that the rocks are sedimentary, and that the foliation and bedding are original and not the secondary results of metamorphic action; or, in other words, the results of pressure.

The proving of this hypothesis, then, reduces the problem to the task of showing that any break in the regular sequence is due either to the cessation or modification of deposition; to subsequent metamorphism which has changed the mineralogical composition and the texture of a continuous horizon; or to the removal of whole series by erosion. Reference here must also be made to seeming breaks in sequence due to faulting, to collapsed anticlines and to other dynamic deformations, which there is no necessity to mention in detail.

There is, however, another possible explanation which has gained such formidable proportions as not to be thrust aside by simple credence or non-credence. Reference is here made to the possibility that the greater part, if not the whole, of the Archæan may prove after all to be eruptive, and that the schistose and foliated structure may have been caused by pressure or shearing, and that the so-called bedding planes may be due to parting planes between successive intrusive sheets.

That the appearance of well-known sedimentary rocks has been perfectly simulated by well-known eruptive rocks, is now no matter for discussion. That schistose rocks, once regarded as undoubtedly Archæan, and utterly barren of life, have been proved to teem with life highly organized, is also beyond dispute. In addition to the numerous granitic and greenstone dikes in the Archæan, which are undoubtedly of igneous origin, there are a large number of other rocks, well foliated, but so strikingly out of harmony with their surroundings as to suggest igneous origin. Near Cranberry reservoir, on the Sussex railroad, is a large outcrop of grayish-white rock. The Sussex railroad cuts through it below the reservoir. In mineral composition it answers almost perfectly to the description of the Saxon granulite. Its feldspar is orthoclase, principally; quartz is a prominent mineral, and even macroscopically the rock is seen to be fil

with minute garnets. Biotite is also present in varying proportions. It is well foliated. At times it would easily pass for a fine-grained biotite gneiss. It appears to be sharply separated from the adjoining rocks, as the garnets and biotite abruptly cease in them. The rock differs from the Saxon granulite in being much more coarsely crystalline, and in having a large proportion of biotite, and in lacking decidedly the mosaic (microscopic) structure of that rock.

Its macroscopic structure, and microscopic as well, seem to ally it to the rocks of the Mount Hope type, while in mineral composition it points to the granulites. On Lake Hopatcong, at Nolan's point, at the railroad station, is another rock of similar composition and texture, save that the latter rock is much coarser. The garnets here are often one-fourth of an inch in diameter, and the other constituents in proportional size. Foliation is yet very distinct.

So far as foliation and bedding go, these rocks have characteristics which would seem to place them among sedimentary rocks.

At Midvale, one mile northwest of the New York and Greenwood Lake railroad, is a rock of identical mineral composition, save that biotite is almost wholly wanting. This rock is so coarse that hardly a trace of foliation is left, and what is present seems to be referable to shearing alone. Its surroundings plainly point to an igneous origin. Here there are three rocks—these are the only known occurrences—widely separated, identical so far as mineral composition is concerned, but one extreme having every appearance of being sedimentary in its origin; the other, the characteristics of a true eruptive. The rock at Nolan's point joins the two.

There are many localities, also, where true eruptive granitic rocks have enclosed within their mass fragments of the adjacent schistose and gneissic rocks. These same granites may be, and often are, sheared in such a way as to simulate foliation or stratification. Areas of this nature may be found near Two Bridges, on the New York, Susquehanna and Western railroad. There is another rock of frequent occurrence in the Archæan, which is almost certainly of igneous origin, but which is beautifully foliated. The rock is a dark gray in color, a gabbro in structure, but it consists of triclinic feldspar, scattering flakes of biotite and occasional grains of magnetite. In other localities, the general appearance of the rock remaining the same, the mineral composition changes to triclinic feldspar, hornblende and mbic(?) pyroxene, magnetite and scattering grains of quartz. ation is only evident when weathering has made some progress.

The rocks are undoubtedly the same wherever found, and were it not for their associations, would be called of undoubted sedimentary origin. But so diverse are their accompanying rock types, that one is almost forced to take refuge in an igneous origin as an explanation of its occurrence. The result of these conflicting testimonies, which cannot, at present at least, be classed under any one general hypothesis, points clearly to the fact that sufficient knowledge of the schistose and gneissic rocks has not yet been obtained to warrant any broad generalizations concerning them. Limited areas must be worked out in detail, and these different areas must be as carefully compared. The results of this method cannot fail to be beneficial, for whether the rocks now called Archæan prove to be sedimentary or igneous in their origin, or a mixture of both, the increased knowledge which such a study is sure to bring, can be turned to account in economic geology as well as in satisfying the demands of pure science.

ECONOMIC STUDIES IN THE ARCHÆAN HIGHLANDS.

As has been the custom of the Survey for so many years, special attention has been paid to all work in this department which tends to advance the economic interests of the State.

Inquiries have been made of the Survey, repeatedly, as to the possibility of obtaining good building-stones, either gneisses or granites, from the Archæan. In the studies of the rocks this question has been kept prominently in mind. In general, it may be said that granites are very rare in the State, save those that are so coarse as to be utterly unfit for building.

The freedom from iron of many of these granites, and the large proportion of orthoclase feldspar in proportion to the quartz, suggest that they might be fitted for potters' use. No experiments to test this have been made.

For many years it has been known that granites existed in Vernon valley, along the eastern foot of Pochuck mountain. The starting up of extensive quarries of grantite on Mounts Adam and Eve, in New York State, and just across the line, has stimulated search in New Jersey.

Mr. Thomas Bright, of Woodport, and others, have purchased land in which this same granite outcrops in New Jersey.

The locality was visited by the writer at the request of Dr. Cook. To all appearances the rock is a true hornblende biotite granite.

Quartz, orthoclase, biotite and hornblende are the principal mineral constituents. The last two minerals are about equally present.

Accessory minerals are pyrite in minute crystals; very rare. Molybdenite is scattered through the entire mass in minute scales. Numerous small but well-formed crystals of zircon are present. Tourmaline is present in the segregated masses.

The rock is rather fine grained and very even in texture and color. It is reported to cut well and to take a fine polish.

As to weathering, it is exposed in dikes in the valley, and great fragments which were blasted from the surface of the exposure appeared to be weathered in no more than one-fourth to one-half of an inch from the natural surface.

The only serious question to be considered is regarding the size of the blocks which can be quarried. The development of the place is so slight at present that nothing definite can be said on this point. The locality is easily accessible by rail.

There is a rock which is very abundant in the glaciated* portions of the State, which has already been briefly referred to. It is the gray feldspathic gneiss of Prof. Smock.† The best outcrop of this rock so far observed, is on the crest of the hill just east of the line of the Hibernia mines. The same rock is found all along this line of iron ore and on either side. An opening has been made just east of the De Camp mine, from which stone has been quarried for buildings in the vicinity of the mine. The rock is a very light gray, almost milky white in general. It consists of quartz, feldspar, a greenish-black mica, with scattering grains of magnetite. The rock is somewhat decomposed, but there is no doubt but that at no great depth very fresh stone could be obtained. It is fine, even grained, and of a pleasant color.

Another rock very similar to this, except that the mica is wholly replaced by magnetite, has been quarried on the summit of a mountain east of Franklin Furnace. The principal objection made to this rock is that it cuts "hard." But blocks of almost any size may be quarried, and of even grain and color. Judging by the resistance to the weather on the exposed mountain tops, where this rock principally occurs, the stone would be very durable, to say the least.

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*The same rock exists in the southern portions of the Highlands, but owing to the great depths to which the rock is weathered, good stone is not readily accessible.

†Annual Report, 1884, page 64.

Rock of this nature is to be looked for on the summits of nearly all of the mountains of the Highlands.

A quarry has been opened by the New York, Susquehanna and Western Railroad Company, near its track, on Dunker Pond mountain. The rock is nearly the same as that mentioned in the last paragraph. Being on a sheltered side of the mountain, it does not seem to have been so deeply glaciated, and is consequently not quite as fresh in appearance.

Mr. Oates, the master mason of the road, tells me that the rock works easier than that from the mountain quarry. The greater weathering probably accounts for it.

Stones of almost any desired dimensions are here quarried.

A quarry, which is not located on the atlas sheet, has been opened east of the Morris County railroad, east of the United States powder magazine at Middle Forge. The stone here is a hornblende gneiss. It is fine, even grained, rather coarser than the ones last mentioned, and the color is a light greenish gray. Large blocks of stone can be quarried, and with but little waste.

There are numerous other quarries from which stone is quarried more or less. The best one, however, appears to be the Delaware, Lackawanna and Western railroad quarry, on the Sussex railroad, below Cranberry reservoir.

ZIRCON—MOLYBDENITE.

Among the minerals of the State which possess economic value and to which little attention has been given, may be mentioned zircon and molybdenite. The first mineral, both on account of its form and its mode of occurrence, will be readily detected when once attention has been called to it.

The form is usually that of a square prism, with beveled ends, which come to a point. The complete crystal in this case, the simplest form, has twelve faces, eight triangular and four parallelograms. (See Figure 4.) The crystals rarely exceed one-half inch in length, and are not often as long. In color they are a reddish brown to black. They are usually very brilliant.

They occur most frequently in a very coarsely-crystalline rock, in which are scattered large, coarse nodules of iron ore.

The mineral is, just at present, very valuable on account of its

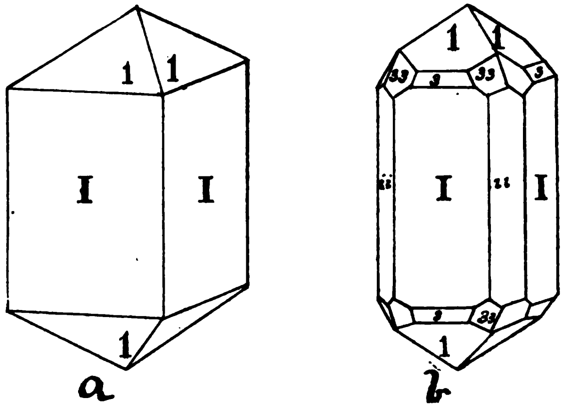

Fig. 4.

ZIRCON CRYSTALS.

(Copied from Dana's "System of Mineralogy.")

proposed use in electric lighting. It is quoted in mineral catalogues at from 50 cents to $1 per pound, pure crystals.

Molybdenite is another mineral of great value. It can with difficulty be distinguished, by an inexperienced eye, from graphite (plumbago, or "black lead"). A very simple test will separate them.

Both "black lead" and molybdenite occur in shining steel-gray scales, and both will soil the fingers and paper. Both are inelastic, and are thus readily separated from black mica. To test for molybdenite, take a few bits of the separated mineral and mix with eight or ten times its bulk of common cooking soda. Put these in a metal spoon and melt over a hot fire.

When the mixture is thorougly fused, cool and place the fused residue on a bright silver coin. If the mineral is molybdenite, upon the addition of a few drops of water the coin will be stained black, from the presence of sulphur.

In the case of graphite the coin will not be tarnished. The mineral is used largely as a chemical reagent in the determination of phosphorus, and retails as high as $3 per pound.

It is liable to be found anywhere in the iron-ore belt. Two localities have been found this summer which would pay well to explore further. The first locality is on the road from Vernon to Wawayanda. The exact spot is well towards the summit of the mountain, where a little brook crosses the road. Work has been done—blasting out a ledge of rocks which crossed the road. In this rock, which is com-

posed chiefly of biotite and feldspar, several fine crystals of molybdenite were found. There were also scattered through the rock numerous scales of the same mineral. Prospecting would be necessary in order to determine whether or not the occurrence is extensive enough to pay for working.

Another locality, which promises even better than the above-mentioned one, is about one and a half miles south of Lower Harmony. It is denoted on atlas sheet No. 2 as hill 473.*

The hill is very noticeable, being round in contour and standing out from the foot of Marble mountain. The rock in which the molybdenite occurs is very coarse, and consists principally of feldspar and quartz. The feldspar is very peculiar in that it has very dark, almost black bands traversing the cleavage faces. The quartz is porphyritic. Accessory minerals are mispickel in small crystals, and molybdenite sometimes in very fine and at other times in very coarse scales.

The mineral is not distributed evenly through the mass, but occurs more or less segregated. No analysis has been made of the rock, but from appearances it is judged that from dressed ore the percentage by weight would run from 0.5 to 2. This would give from ten to forty pounds per ton. On an average of $1.50 to $2 per pound the place would be well worth working.

There are several places where zircons are found in such abundance as to give promise of economic importance. On a piece of land owned by Mr. A. S. Woods, of Stockholm, N. J., several openings have been made in search of iron ore. The rock in which the openings were made is a very coarsely-crystalline aggregate of quartz, feldspar, and occasional crystals of pyroxene. Magnetite and titaniferous iron occur so abundantly as to be prominent constituents of the rock. Associated with these are numerous well-defined crystals of zircon. The mineral occurs in the quartz usually, but is sometimes included in the feldspar and magnetite. In the latter case the crystals are much smaller. Specimens can be taken where the zircon amounts to fifty per cent. of the mass of the rock. Taking it as a whole, the percentage would reach from two to five.

Should mining for this mineral be attempted, the ore could be sorted very easily, as a glance would soon show whether or not the mineral was abundantly present.

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* For the sake of exact reference, throughout this report, particular localities are referred to the altitudes of hills as denoted by figures on the State maps.

The only locality where zircon is now extensively mined is in Henderson county, N. C. Here the mineral occurs in a decomposed granite, in which it is wholly detached from the matrix. The whole decomposed rock is shoveled into sluices and the crystals are washed free from their associates. In the New Jersey localities the rock containing the zircon would have first to be crushed in order to free the mineral from its gangue. The crushed matter could then be shoveled into sluices in which riffle bars were placed. The great difference in the specific gravities of the rock constituents would effect a ready separation by means of water. In some experiments tried by the Survey a sluice-box twelve feet in length was employed. The zircon with magnetite and other iron ores was wholly caught on the first three riffle bars. The other constituents of the rock were either washed entirely from the sluice or caught on the lower bars.

The zircon and iron ores were dried and then subjected to the action of a powerful electro-magnet, when the iron was wholly taken away, leaving the zircon free. A powerful magnet is necessary, on account of the feeble magnetic action of the titanic iron.

Another promising locality is the Henderson mine, in what is known as the "Double Run Meadows," north of Dunker pond.

Numerous crystals were also found on the east slope of hill 781, one mile northeast of Cranberry pond, northeast of Rockaway.

Other localities have been observed, but at the above-mentioned ones zircon was present more abundantly than at any others. All localities noticed bear a strong resemblance to each other, in the general appearance of the rock itself, its mineral constituents and its association with other rocks. The rock is always very coarse. The feldspar is principally orthoclase, and the quartz frequently occurs porphyritic. The principal minerals are quartz, feldspar, magnetite, titanic iron and zircon. Minerals present, but less abundant, are pyroxene, (?) biotite, sphene, rutile and apatite. Occasionally, even in its coarsest masses, the rock has a foliated appearance, or a parallelism in the arrangement, which is probably due to shearing or "stretching." Indications of this exist in the appearance of the minerals. The zircons, especially, are often bent, sometimes broken, slightly displaced and healed. Both the quartz and feldspar present the same appearance. Included within the rock mass itself are numerous fragments, very angular, of a dark diorite-appearing rock. These fragments consist almost wholly of hornblende, feldspar, a little biotite and scattering grains of magnetite. Fragments of a rock

composed wholly of quartz, feldspar and grains of magnetite are also included.

Fragments of this nature are much more abundant on the edges of a mass, and they extend but a short distance in towards the center. The enclosing rock is so closely knit, by the partial solution and re-crystallization of its minerals, to the intruded fragments, that when a little care is exercised hand specimens may be broken off which show the fine-grained foliated rock and the coarse matter forming the host. The facts of the rocks surrounding this particular locality at Stockholm are as follows:

One mile west of Stockholm, on a ledge north of the railroad, the rocks dip east-southeast rather steeply.* Near Stockholm proper the dip is north, 50° east, to the amount of 60°. Below Stockholm the rocks change to north, 70° west, amount moderate. Railroad cut near Stockholm, and north of Dunker Pond brook, the dip is south, 65° east, amount 60°.

Northwest of Stockholm a line of rocks, forming hill 1,220, strike northwest and dip to the northeast. A line of magnetic attraction, traced by Mr. Sebenius, M.E., follows the strike for nearly the whole length of the hill. Southeast of this place the strike of the hills becomes normal, the dip is southeast, and a line of attraction follows at right angles to the other or northeast. The dip of the rock is here southeast. A mile southeast of Kincaid's hotel another line of attraction runs northeast. One mile below this, a little north of hill 1,052, another line of attraction starts in and runs nearly due north till the other line of attraction is intersected on hill 1,227.

Aside from the facts above stated, there is other evidence that goes to show that the rocks have been greatly disturbed in very early geological time, or at least long previous to the exposure of these rocks by denudation. Several cuts along the line of the New York, Susquehanna and Western railroad in this vicinity show large, smooth walls of slickensides. Careful study has also shown that the rocks do not match on either side of the line of the railroad.

Reference has already been made to the rocks which enclose such ore deposits as the Mount Hope belt. It was stated that the rock enclosing this ore was made up of quartz, feldspar and grains of magnetite. This rock also comprises the greater part of the rock on

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*These dips are taken from the Annual Report State Geologist, 1883, page 44. They agree with the notes of the writer.

the plateau of Lake Hopatcong and many other places. This rock is also interstratified with a dark hornblende rock which frequently is intimately associated with workable beds of iron ore.* Numerous openings in search of iron ore have been made where this rock occurs.

Putting these facts together, one can legitimately infer that the zircon rock thus referred to must be, first, a segregated rock from the feldspathic gneiss of Prof. Smock; second, an eruptive rock from the fused lower strata of the feldspathic gneiss;† or third, which seems most probable to the writer, an eruptive rock of unknown origin.

The included angular fragments of the hornblende rock and the feldspathic gneiss would seem to be contrary to what we would expect of a segregated mass. It is difficult to imagine the lower part of a bed fused and thrust through the upper members, which are solid enough to break off into angular fragments, and retain their shape. If, however, we think of the caverns and fissures which would be formed in the folding of these rocks into anticlines and synclines. as being filled with molten rock, either fused by fire alone or by the agency of heat and water, the matter has a different aspect. The great mass of rock above would for a long time shut in the heat of the erupted rocks, and by the time that they were exposed by denudation from above, their coarsely-crystalline texture would have been assumed and permanently fixed.‡

What is true of this one particular locality is true of many others which have been visited, with this exception, the zircons are not everywhere so abundant. The correct understanding of the nature and occurrence of this rock is of no little importance to prospectors and property-owners in the mining belt. There are hundreds of openings which have been made in rocks of a similar nature. In some places thousands of dollars have been expended in a vain search for paying ore. Shafts have been sunk and tunnels driven, and the prospect was no better at the end than in the beginning. Many other localities have been operated only at the expense of comparatively little money, the shafts having been sunk only a few feet, not deep enough to encounter troublesome water.

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* See Annual Report State Geologist, 1884, page 65, last part of second paragraph.

† See Dr. Lawson's report of the Lake of the Woods Region, Part C.C., Annual Report of Canada Geological Survey, 1885, where he seems to hold that the lower strata of a formation may be fused and intruded between the upper members.

‡ See Rosenbusch's Microscopic Physiography of Massive Rocks, German edition, page 4.

So far as the writer has been able to learn, out of all these mines thus opened, at whatever expense, not one has ever returned one cent of the outlay through the sale of ore. These places may at once be recognized by even the most inexperienced. First, by the rocks themselves. They always weather into a dirty, rusty clay, filled with coarse nodules of iron ore and quartz in the unglaciated regions, *i. e.*, generally speaking, south of a line drawn from Morristown, through Dover, to Buttzville, Warren county.

In the glaciated regions, north of this line, the rock is usually of a milky white, with irregular nodules of quartz and dark masses of iron ore and pyroxene.

In all places the surrounding rocks are much disturbed. Gone over with a dipping-needle the attraction begins suddenly as one goes into the field and ends as suddenly on leaving it.

There is no particular *line of attraction*. One spot may give 90° and not ten feet away the needle may swing back to 0°. If the attraction is continuous it is fluctuating. In short, the ore body resembles a "chimney" or "blowout" of the western miners. Even were the ore in paying quantities otherwise, the presence of large masses of titanic iron and numerous small crystals of apatite would prevent its use. In case, however, of such localities being worked for zircon, necessitating the use of a magnetic separator, the non-titaniferous ore could be separated from the other, and it would thus become marketable.

During the prosecution of the work attention has again been compelled to the presence of graphite in the Archæan rocks. An almost continuous line has been found of thirty-five miles in length. The line commences at the old graphite mine three-fourths of a mile south of High Bridge. Its direction at this point is north, 48° east. It bears towards the east to Washington valley, west of Morristown, where its general direction is about north, 52° east. At this point it suddenly turns north, 30° east, to near Denville.* From this point it bears north, 35° east, to hill 1,062, east of Stickle pond, where it stops. It again begins on the north side of the Pequannock river, but there is an offset of one and one-fourth miles to the southeast. This line has not been traced farther. A similar rock has been found

* Between Washington valley and Denville the graphite has not been found. From the exceedingly broken and disturbed condition of the rocks it is doubtful if it exists there. As will be shown later on, this disturbance is due to faulting, and the overlying beds have been unmoved, except, perhaps, in isolated patches.

at Iona island, in the Hudson river, thirty-five miles northeast. Another line of graphite-bearing rock is found on Bald hill, two and a half miles southeast of this. It has not been traced to the southwest, but it is supposed to run under the Triassic rocks near Boonton. To the northeast the line runs through the Bloomingdale graphite mine. On the north side of the Pequannock river a much older rock cuts it out for about one mile. It is resumed at a point where a brook from Mud pond crosses the New York and Greenwood Lake railroad, and is traced almost continuously for a distance of six miles. It is presumed to come out on the Hudson at a distance below Iona island, corresponding to its distance from the first-mentioned line.

A third line of graphite gneiss is found on hill 833, east of Pompton station, on the New York, Susquehanna and Western railroad. The hill is on the range of Ramapo mountain. The line has not been traced continuously, but a graphite-bearing rock was encountered on the interstate line, two miles southeast of Lake Patoque, formerly Negro pond. Other somewhat isolated patches of graphite have been found, which may be traced into lines, but have not been at present. One of these is in Dark hollow, on the east slope of Bowling Green mountain, one and a half miles northeast of Berkshire valley. Graphite is is also found about one and a fourth miles northwest of this, just east of hill 1,113. As Dr. Cook speaks of this hill (1,193) as lying in a synclinal fold,* and Dr. Britton, in his report, mentions the same thing,† it is more than probable that this is a continuous bed, seen on two opposite edges of its fold. The same, or a similar graphite rock, outcrops for about a mile, near the farm of Mr. S. F. Card, three miles (by road) northeast of Kincaid's hotel, at Stockholm.

Graphite also is found by the roadside east of Pacack brook, on the northern point of hill 1,277, a little below the cross-roads west of Canistear mines. At several places mentioned mines have been opened, but at only two places, near High Bridge and near Bloomingdale, have mills been put up for refining the graphite. There is, however, good reason to suspect that when it has such an extensive occurrence as it has in this State, that it may yet be found in paying quantities. A rock very similar to the New Jersey rock is worked at Ticonderoga, N. Y. This rock carries from eight to fifteen per cent. of graphite and it pays well for working. The retail price now is quoted at ten cents per pound.

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*Annual Report State Geologist, 1886, page 72, Figure 2.

†*Ibid.*, page 78, Figure 3.

III.

GEOLOGICAL STUDIES OF THE TRIASSIC OR RED SANDSTONE AND TRAP ROCKS.

During the year little field-work has been done on these rocks directly. Yet, as was suggested in the report of last year,* the work in the Archæan Highlands of the State has done much in throwing light upon the geological questions affecting this formation. By the kind invitation of Prof. Wm. M. Davis, of Harvard University, the writer was enabled to look over a portion of the Connecticut Red Sandstone Area.

Only three days were spent in the vicinity of Meriden, Conn., but enough was seen to convince the writer of the correctness of Prof. Davis' views as to the extrusive origin of many of the Connecticut traps. At the same time nothing was seen to warrant the changing the views which have been and are still held regarding the origin of our traps. The views which have been advocated by the New Jersey Geological Survey are as follows: †

"1. That the sedimentary Triassic formation was originally deposited in beds, which were nearly level.

"2. That while some of the materials of which it is composed were drawn from the higher grounds surrounding it on all sides, the chief supply came from the Archæan rocks on the southeast border.

"3. That the eruptions of the igneous or trap rocks followed the upheaval of the sandstone.

"4. That the trap rocks are necessarily intrusive, though they may overflow for short distances, from the outcropping edges of their intrusive sheets.

"5. The curved lines in which the ridges of igneous rock run are due to the form and surface of the Archæan and Primitive rocks, which underlie the Triassic, and their convexity towards the southeast is due to the upheaval being on that side of the belt."

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* See Annual Report State Geologist, 1888, page 42.

† See Annual Report State Geologist, 1886, page 126, bottom of page.

With respect to paragraphs 3 and 4, it was thought that the discovery of the trap conglomerates on the northwest border of the formation, near Montville, might possibly modify, to some extent, the hypothesis regarding the intrusive origin of the traps. An incidental study has revealed at least two points which it is well worth while to dwell upon. These points are:

First. The trap and associated conglomerates are different with respect to their bedding than the other conglomerates of the formation.

Second. The trap pebbles may have come from another source than from the traps at present within the area of the Trias.

In the report of 1888, these conglomerates were referred to as Series III. They are described as consisting, in different localities, of heavy beds of pure limestone breccia, limestone breccia intermingled with well-rounded pebbles and boulders of other rocks; a conglomerate made up wholly of mingled gneiss and quartzite pebbles; this grading easily into a conglomerate made up almost wholly of trap.

This bed of conglomerate is, in one sense of the word, very thick. That is, it is thicker than any other known bed of the Trias. In fact, no bedding planes whatever are discernible. This could hardly be expected in a material so coarse, which forms the bulk of the conglomerate, and it is in direct contrast to the appearance of other conglomerates of the Trias. In the "pebble bluffs" at Milford, on the Delaware, there are quartzite pebbles at least one foot in diameter. Smaller ones are also present, and the interstitial matter is fine sand and a reddish mud hardened into stone. Yet, these beds of pebbles are not continuous. They vary from one foot to six feet in thickness, and are succeeded by beds of finer material, sometimes a real sandstone, though rather coarse. In short, on the whole face of the bluff, bedding planes are distinctly visible, and this face is nearly three hundred feet above the road. No such exposure occurs in the trap conglomerates. They occur as foot-hills to the Archæan, and their outcrops are limited to patches washed bare on the summit of a hill, or exposed by the action of small streams. The hills which are thus apparently made up of these conglomerates stand from three to four hundred feet above sea level. It is judged that at least two hundred feet is not too large an estimate of the thickness of the bed. The reason for assuming this is, the conglomerates have been found on the

summit of a hill three hundred and seventy-seven feet high, and at different places at levels down to two hundred feet, or lower.

Whether or not the shape of the hills is due to the drift material, which is abundantly present, is hard to say. It is, nevertheless, true that the longer axes of these hills are more frequently at nearly right angles to the strike of the Triassic rocks than parallel to it. It will also be noticed that these hills are wholly located on the Archæan border, and are invariably opposite deep cuts or notches in the Archæan rocks. This is true in the conglomerates in New York State also. It cannot be proved, at present, that all of these hills are composed of a conglomerate rock; there may be some drift, but alternating hills of conglomerate have been found.

It is a well-established fact the country extending from Liberty Corner on the southwest to Pompton on the northeast, and from the range of the Archæan on the northwest to the Watchung mountains on the southeast, has been the bottom of a large lake. This boundary includes "Great Swamp," "Black and Troy Meadows," "Hatfield Swamp," "Long Meadow," "Great Pine Meadow," "Bog and Vly Meadow" and "Pompton Plains." With the exception of Pompton plains all of the localities above named are now so swampy as to be unfit for cultivation. A good part of Pompton plains is also covered by a swamp. The soil for many feet in depth in these swamps is a black peat or muck. Clay-beds are occasionally found. Beds of large pebbles—"cobblestones"—are also to be met with.

In short, a careful study of the locality seems to point strongly to the conclusion that along this nortwestern border streams have discharged their loads at the mouth into the deep waters of a lake. The shape of the hills, rounded to the southeast, appears to warrant this conclusion. The lake has certainly been there, and the well-rounded water-worn pebbles indicate the action of streams.

The next question that presents itself concern the pebbles of trap. If the trap pebbles are the same material as those of the trap ridges to the southeast, and there is no other source of derivation in this direction, these hills must certainly be much younger than the traps.

There are two points to be considered:

First. Are the trap pebbles and trap ridges similar in appearance?

Second. Is there any other possible source of origin?

With regard to the first question. The trap pebbles found in the conglomerates are most of them subangular in form and are rather

larger than their associates. They are too badly decomposed to study exhaustively, either by chemical analysis, specific gravity, or in thin sections. Yet the structure indicates either a diorite or a diabase. The feldspar crystals are numerous and are lath-shaped. Magnetite is present.

The pebbles are coarse grained, that is, the essential minerals could be determined with the naked eye. This would indicate that the greater number of the pebbles came from a rock that had cooled slowly and at a considerable depth. This idea is strengthened by the fact that no gas holes are present, the rock being very compact. Hook mountain, which is the nearest point of visible supply, presents at every exposed surface, points wholly at variance with the above. Where a fresh piece is attainable, a fresh fracture shows the rock to be fine grained, almost aphanitic in texture. Moreover, it is filled with gas pores, sometimes spherical, at other times elongated. They are uniformly present. The amygdaloidal cavities are filled with zeolitic minerals sometimes, though generally they have been dissolved away. Not only is this true of Towakhow or Hook mountain, but it is also true of Riker's hill and Long hill, and it is eminently true of the Second mountan of the Watchungs. Near Orange, on First mountain, these cavities are also found. It is highly probable, therefore, that search must be made elsewhere for the original source of these trap pebbles.

In the report of the Survey for 1886, Dr. N. L. Britton mentions no less than eight dikes of diorite and diabase, which he discovered in the progress of his work in the Archæan.*

During the summer the writer has found at least twenty additional dikes, which do not appear to have been mentioned in former reports. Among those located not more than three miles from the Triassic boundary of the Archæan, are the following:

A small dike of trap in the Archæan, one mile northwest of Pottersville. It outcrops in the road, though it is but poorly exposed.

In Rockaway valley, on the southern point of hill 701. It is between the public road and the Rockaway river, just north of a bridge crossing it. This dike is one-fourth of a mile long and two or three hundred feet wide. The rock is fine grained and compact.

A small dike near pond 667, northeast of Rockaway valley. The rock is aphanitic. The dike is small, not observed more than ten

* See Annual Report State Geological Survey, 1886, page 106.

feet; the width is three feet. A very large dike, one-half of a mile long, at least, and from one hundred and fifty to two hundred feet wide, is found on the eastern foot-hill of hill 1,034, east of Split Rock pond. As would be expected from a dike of this size, the rock is rather coarse textured, comparatively.

Another large dike is located at the Blue mine, west of Midvale.

A large dike ends in the road just west of the New York and Greenwood Lake railroad, three miles above Wanaque. The rock is rather fine grained, but many of the minerals can be recognized by the aid of a pocket lens.

Another large dike is near the new silk mill at Pompton. This makes eight new dikes added to the list this summer. Dr. Britton mentions about four more which occur along this border.

These dike rocks are, with one or two exceptions, characterized as being very fresh in appearance and nearly all of them rather fine grained. A macroscopic examination shows no mica in any of them, and they can probably be safely classed as diorites or diabases.

Another thing which may be mentioned incidentally is the fact that, with a single exception (the small dike near pond 667), these dikes all have their major axes parallel to the trend of the Archæan, *i. e.*, northeast-southwest.

It is highly probable that not one-tenth of the surface of the country, even in the Archæan, is free from soil and drift of various kinds. Of this tenth, probably not more than one-half of the outcrops have been examined. It appears, then, that no very great liberty with facts is taken, if we assume that the number of known dikes may be doubled or even quadrupled.

It is, then, to be safely assumed that the chances for an Archæan origin for these trap pebbles are at least even with those of an origin from the Triassic traps.

Certainly the dike in the Triassic, from which these pebbles could have been derived, is not now in sight.

The origin of the limestone conglomerates, or breccias, rather, is certainly from the northwest, as it has been conclusively proved that the fragmentary limestone is the same as that now quarried at Peapack and other places.

The presence of quartzite pebbles and of a peculiar red slate in the conglomerates of "Pebble Bluff," near Milford, and in a conglomerate near Pompton, has been repeatedly noticed. They are wholly, or

nearly so, absent from the trap and limestone conglomerates, though in the first-mentioned conglomerates, occasional pebbles of limestone are found. It is probable, therefore, that the greater part of these conglomerates are the debris of the limestones and associated rocks of the Green Pond mountains.* But few traces of these limestones remain.

The gneiss must also come from the northwestern rocks.

These additional facts only make it still more probable that the trap pebbles had their origin in the Archæan field, and so have no adverse influence on the import of paragraphs 3 and 4, which hold to the intrusive origin of the traps.

Another point which has excited much discussion, the cause of the universal monoclinal structure of the sandstones, has been indirectly investigated during the year's work in the Archæan.

Although the existence of faults in the Archæan, running parallel to the trend of the mountains, and also at right angles to this line, has been taken for granted, there is a necessity for proof before any structure can be raised on this hypothesis. Numerous minor faults have been noted, for instance one at the Hurd mine, of 150 feet vertical displacement, noted in the Annual Report for 1883. Along the road from Andover to Stanhope, it is noted that the rocks there strike nearly east and west. Numerous offsets in mines also bear testimony to the fact that the Archæan rocks have been subjected to differential movement. From Berkshire valley, along the line of the Rockaway river, to Dover, the rocks, wherever exposed, are broken into small angular blocks, upon the sides of which are numerous slickensides. Between Dover and Denville, near Dover, and also near Denville, are great dikes of a coarse granite, which have intruded themselves into the fractures. The rocks thus broken have been more readily attacked by meteoric agencies, and valleys have been formed, leaving, oftentimes, the eruptive granites as bases or low, dome-shaped hills. Almost without exception the valleys or "cloves" which intersect the hills of the Archæan have rocks badly broken, if they are in sight at all, while the hills along their crests show ledges of solid rock. These rocks are occasionally seamed, but in general blocks of from twenty-five to one hundred or more feet in length could be quarried from these ledges. Add to this the very

* For the age of these rocks, see Mr. Merrill's report on the Green Pond mountains, Annual Report State Geologist, 1886, page 112.

patent fact that the major axes of these hills from one "clove" to another are not level, but are inclined to the northeast, and the probability of cross-faulting is reduced almost to a certainty.

That the Pequannock river flows in such a fracture, there is no doubt. Mention has been made of a line of graphite rocks reaching from High Bridge to within a distance of two miles of this river. The line of continuity is here broken, and is not resumed on the opposite side of the river. The same rock is found one and a fourth miles below. Mention has also been made of the fact that the Mount Hope beds of iron stretching from near Chester pass under the Green Pond mountains at the Howell mine. The rocks across the river are of a wholly different type. Taking these facts, in connection with the great masses of eruptive rocks of the granitic type which occur near here, it makes at least a strong presumptive evidence in favor of these lines of cross fracture.

Briefly reviewed, the line of argument last year (Annual Report State Geologist, 1888) was to this effect:

First. The major axes of the great trap ridges are parallel to the monoclinal ridges of the sandstones, and these to the ridges and valleys of the Archæan.

Second. The minor axes of the crescents are parallel to the cloves of the Archæan, as indicated by the courses of streams.

Third. The courses of streams in the Archæan are determined by faults or fractures.

Fourth. These coincidences could not be unless there is a common cause. This cause was assumed to be the fractures which extended under the Triassic formation, forming lines of weakness through which the great ridges were pushed up. It is assumed that if sufficient movement in any one of these fractures took place, thus allowing one dike to be erupted, the same must be true of all, and as the majority of the New Jersey traps are known to be intrusive, it is assumed that all must be.

All work done in the Archæan this summer, which bears on this question, favors this interpretation of it. Yet, it is to be hoped that further and direct work will put this question beyond doubt.

IV.

DRAINAGE.

BY GEO. W. HOWELL, C.E.

PEQUEST DRAINAGE.

During the year 1889, a rainfall of nearly 65 inches is reported. The average for the past forty-five years is 46¼ inches. Only two years in that period at all approach the amount for 1889. In 1859 and 1888, about 57 inches of rain fell.

This unprecedented rainfall has proved the great value of the improvements made along the Pequest river, through the Great Meadows, in Warren county. The channel through the meadows has easily carried all the water. A portion of the tract, however, near the outlet, has occasionally been submerged, owing to the obstructed condition of the stream below the point where it leaves the meadows. The result has been serious loss to crops, especially hay and grass. Detailed reference was made in the last Annual Report to these obstructions, and plans were there suggested for their removal. It does not appear that any steps have been taken to remove the difficulty. A recent examination of the locality has shown that the expense of the necessary work will be very light, and the benefit great to the lower part of the tract. The legal provisions are ample.

The area of improved land is annually increasing and the lands now under cultivation show a marvelous fertility. The production the past year has been more than double that of the surrounding uplands. Messrs. Arnold and Stevens, who own a large tract at the upper end of the meadows, report a yield in bushels per acre—corn, 140; potatoes, 300; turnips, 700; carrots, 1,000; and other crops in like proportion. In this part of the tract the drainage seems to be perfect.

At the lower end Messrs. Swayze and Davis report hay crops destroyed from the causes referred to above. Their hay usually runs 1½ to 2 tons per acre. They had in 65 acres of onions, which

ordinarily yield several hundred bushels to the acre, but which the past year have proved almost a failure. This is not on account of freshets, for the land on which they were raised was not submerged, but on account of the general wetness of the season. These gentlemen are turning their attention largely to the raising of celery. They have imported a colony of Hollanders, from the great celery-raising district near Kalamazoo, Michigan, and have had some 30 acres planted. The crop has been reasonably good, considering the season.

The results of the drainage are very marked in the improved sanitary condition of the district, as shown in the absence of fogs and malaria.

With the additional improvement suggested in clearing out the outlet, the Pequest drainage scheme may be considered a complete success.

PASSAIC DRAINAGE.

Since the date of the last report active operations have been begun. The commissioners have issued bonds and sold thus far about $40,000 at par. A contract was made with Alfred B. Nelson, Esq., of New Brunswick, over six competing bidders, for the entire work, at prices varying from $1.67 to $4.80 per cubic yard for rock excavation at Little Falls, according to locality; for earth and boulders at Two Bridges, 46 cents, and for earth at Pine Brook, 31 cents. The contractor takes 45 per cent. of his pay in bonds at par.

The head of the main fall has been blown down, but work in that narrow gorge has been temporarily suspended on account of the extraordinary freshets of the past season. The plant was removed to the reef just above the dam. A 40 H. P. boiler on shore runs the steam drills, which work from a float standing on the submerged rock by means of adjustable legs at each corner. Holes are sunk to a depth of six to eight feet, reaching two feet below the grade line, to insure a thorough breaking up of the bottom. These holes are placed about four feet apart each way, and as soon as drilled they are charged with dynamite cartridges. When fifteen to twenty holes are thus charged, the platform is removed and a mattress of rough poles woven together with wire is floated over the spot, to prevent flying stone from injuring the adjacent buildings. The charges are then set off by a battery on shore.

The results so far have proved quite satisfactory, the rock being broken up small, and formed into a mound rising above the surface of the water. The broken stone is loaded upon scows and removed to the bank.

It is expected that the work will be pushed through the winter, and it is hoped that by next season it will have reached such a state of advancement that some practical benefits may then be experienced.

V.

WATER-SUPPLY AND ARTESIAN WELLS.

WATER-SUPPLY.

BY C. C. VERMEULE, C.E.

The year has been productive of much new water-works construction and of many inquiries as to new sources of supply, from cities and towns which have outgrown or are otherwise dissatisfied with their existing works.

The most prominent cases are Newark and Jersey City, where the danger of using the contaminated waters of the Lower Passaic, so often urged in these reports and elsewhere, has impressed itself upon the citizens and brought about effective action looking to improved supplies. Newark has made a contract with the East Jersey Water Company for a new and pure supply which will be drawn from the Pequannock river above Bloomingdale, a source unexcelled for quality by any in the State. This water company has a capital of $3,000,000, and seems to have been an outgrowth of the ownership of the Morris canal by the Lehigh Valley railroad, including, of course, the claims of the canal company to various water-sheds which have long been in use as feeders of the canal system. Amicable arrangements have been made between this company and the "Bartlett syndicate," so-called, which controlled valuable rights in the Passaic head-waters.

By the terms of the contract with Newark the East Jersey company is to deliver, by gravity, at a head of 300 feet above tide, which is 65 feet higher than the highest hill in the city, a supply of 27,500,000 gallons daily, at a total cost to the city of $4,000,000. At the end of eleven years an additional payment of $2,000,000 will secure to the city a supply of 50,000,000 gallons daily. When the plant is constructed in accordance with the specifications, acceptably to the city authorities, it is to be turned over to the city and operated by it.

The present system supplies 14,000,000 gallons, and has cost to date $2,671,580, exclusive of real estate, interest and maintenance. When the new supply becomes available the extensive pumping plant at Belleville will become useless. The remaining works, including the four distributing reservoirs with a combined capacity of 46,000,000 gallons, and the distribution system with 161 miles of mains, will continue in effective use.

The present debt being $3,500,000, the $4,000,000 of new debt will make a total of $7,500,000, with an interest charge of $300,000. The present revenue of the Aqueduct Board is $340,000, and it is estimated that this will reach $410,150 by 1892. This will leave $110,150 for operating expenses. The operating expenses of the present plant is given as $103,407 annually. The above figures are very gratifying in that they show that without increasing the rates now charged for a most unsatisfactory supply, Newark will obtain a supply which, considering its quality and its delivery by gravity, will probably be unequaled by any city of its size in the United States. The effect on the growth of the city cannot but be very appreciable.

There was much opposition manifested to letting any contract for a supply to a private corporation, and the usual arguments against private ownership of works were advanced. It is to be said, however, that most of the difficulties which have arisen, and most of the grievances which have been expressed against private water companies, have come from the distribution of the water to individual consumers. It is to be borne in mind that the East Jersey company has nothing to do with the distribution of water. It simply proposes to deliver the water to the cities in bulk at so much per million gallons, or else to install the plant of a given capacity, and then sell outright to the city at a fixed price. The distribution of the water from its reservoirs is, in any case, left to the cities.

In Jersey City the question of a supply has been fully discussed, but no definite action has yet been taken. Propositions from both the East Jersey and the Montclair companies are under consideration. Opposition to letting the contract to private capital has also been expressed here. The East Jersey Water Company has offered to supply the city for $39 per million gallons. In the admirable Manual of American Water-Works, published by "Engineering News," 1888, to which reference has been had for some of the figures contained in this report, we find that the cost of the present Jersey City works has been $4,950,000. The debt is $4,838,000. Annual operating expenses,

$539,170. Annual revenue, $514,428. The present consumption is 16,500,000 gallons daily, which, at above rates, would cost $175,000 yearly. The present cost of pumping from the Passaic may be estimated to be $102,300, not including interest on cost of pumping plant. Including interest at 4 per cent. it will be about $135,000.

Supposing the present debt to draw interest at 4 per cent., as in Newark, we have for interest $193,520; for 16,500,000 gallons of water daily, at $39 per million gallons, $175,000; total, $368,520. This deducted from the revenue leaves about $146,000 for maintenance. This seems about in proportion to the operating expenses of the Newark works, allowing for the extra lengths of conduits, &c. It would appear that Jersey City would find this plan as advantageous as Newark.

The problem of water-supply for the district east of the Orange mountain is, in some respects, a peculiar one, and the necessity of treating it in a comprehensive manner, has been often urged in the reports of this Survey, in the report of the Commissioners of State Water-Supply, submitted to the Legislature in 1884, and elsewhere. We have here, from Paterson on the north to Elizabeth on the south, a population of some 600,000, on 150 square miles of upland, averaging 4,000 to the square mile. The population of the district is much too dense to make it safe to adopt any source of supply lying within the area, and both this district and the country adjacent are covered with a soluble red soil, which makes it absolutely necessary to go to the Highland region on the west, where there is an abundance of wonderfully pure and wholesome water. This course is too expensive for the smaller towns to adopt independently, and the difficulties in the way of concerted action are apparent, when it is considered that this population is embraced within eighteen incorporated cities and towns and a host of unincorporated villages. In consequence, these smaller towns will be left to draw their supplies from local sources, while the larger towns secure, independently, pure supplies from a distance. The increase in density of the population of this area is extremely rapid, and the result is sure to be dangerous pollution of the local sources, whether they be wells or streams. It has been proposed that this matter be taken in hand by the State and proper plants installed, to be paid for by assessment on the parties benefited. This plan would doubtless meet with so much opposition that very serious delays would be experienced at best. It would now

appear that the solution of the problem will be reached through the private corporations. A water company has already been in operation for eight years, which is working on this principle of combining several towns in one system. The Hackensack Water Company, Re-organized, pumps its supply from the Hackensack river, at New Milford, and has distribution systems in Hoboken, West Hoboken, Union town, Weehawken, Guttenberg, North Bergen, Ridgefield, Englewood and Hackensack. In all, nine villages and towns, with an aggregate population of about 75,000, are supplied by this system. It would have been difficult for many of these places to have secured independent supplies.

The important part which the topographical maps of the Survey are to play in the solution of this great problem is indicated by the remark of the eminent hydraulic engineer, Mr. Clemens Herschel, Chief Engineer of the East Jersey Water Company, that without them the work which he has accomplished would have been almost an impossibility.

Camden is also discussing the possibility of obtaining a better supply. The present one is pumped directly from the Delaware river, near the city. It has become impure. The fouling is said to be in danger of increase from the construction of the Fisher's Point dyke by the United States Government. The plant has cost $700,000, including the distribution system, which will not be affected, of course, by the change. A proposition has been made by a corporation to purchase the works from the city for a sum not to exceed $500,000, but it meets with decided opposition.

East Orange is nearly doubling the capacity of its pumping plant and wells. Atlantic City, which has been supplied from a creek and open well on the mainland, is now about to secure a supply from driven wells, having already obtained a flow of 150 gallons a minute from an eight-inch well 625 feet deep. More or less dissatisfaction has also been expressed as to the supply of New Brunswick, Perth Amboy, Elizabeth, Burlington and Bordentown. Mount Holly is about obtaining an improved supply.

We have thus the startling aggregate of eleven towns, with a population of 455,823, or more than one-third of the people of the State, dissatisfied with their present source of supply. The works involved represent an aggregate cost of $10,000,000. The leading cause of trouble is the pollution of streams by other towns. The supply of

383,801 people is now affected by this contamination, while 61,694 have been affected by natural unfitness of their sources of supply.

Our boards of health have awakened a public sentiment which will not tolerate longer unwholesome water-supply. The result of the present movement will be of incalculable benefit to the State. From a sanitary point of view it is a hopeful sign of the times.

Ten towns and villages, aggregating a population of 30,000, have now under construction or are projecting their first water-works. The largest of these is Plainfield, with 8,913 inhabitants by the census of 1885. While this beautiful city is in other respects most progressive, it has for some time been the largest east of the Mississippi unsupplied with water. A supply from driven wells, situated in the northern part of the city, is said to be contemplated. At least six out of the ten new works will draw a supply from wells.

Of the 56 water-works in the State which supply towns, 43 have streams for their sources, and 13 draw from wells. Eight of the latter are large open wells and 5 driven tube wells.

Classified as to ownership, 38 of the towns are supplied by private corporations, and 18 own their systems. Of the latter, 13 were built by the towns, and 5 by private capital, being afterward bought by the towns. Among the cities not owning their water-works are Paterson, with a population of 63,273; Hoboken, population 37,721; and Elizabeth, population 32,119. Newark, Camden, Trenton, New Brunswick and Burlington, have found it expedient to purchase their works from the companies.

The question as to which is the more desirable—city ownership or private ownership—must be independently determined in each case. There are great advantages arising from the maintenance and the control of distribution being in the hands of the cities; but still very many cases may be cited in this State, where private capital has filled all the requirements of a good, efficient service. The statistics show that a large majority of the smaller towns prefer this method. There is no doubt that the uncertainty as to the cost of large undertakings under municipal control enters as a factor in the problem very often.

The importance of the subject to the people of the State is apparent from the fact that two-thirds of its population are now dependent on systems of public water-supply. The pollution of our streams goes hand in hand with this, and, as we have seen, now directly affects one-third of our population. On the Delaware, Bordentown, Bur-

lington and Camden suffer from this cause; the sewage of Trenton being responsible in the former two cases. On the Passaic, Newark, Jersey City and Bayonne have been driven out by the sewage of Paterson and Passaic. The adjustment of troubles from this cause gives rise to some very nice questions. Is a stream more necessary to the town below for water-supply than it is to the town above for drainage? It would seem that the Delaware below Trenton, and the Passaic below Paterson, are the natural sewers of their respective districts, and must be abandoned to that use.

It would appear to be the time for a more active and direct control of these matters to be assumed by the State. The initiative was taken by the act of 1883, authorizing a commission of State water-supply, but this commission was not continued. The control of the construction of dams, the prevention of unnecessary pollution of streams, and guarding of cities against the adoption or use of contaminated sources of supply, would be the proper work of such a commission.

In all of the Archæan and Paleozoic districts of the State—the Highlands and Kittatinny valley—there is an abundance of pure water obtainable from the streams. There is no difficulty in finding a gravity supply, near at hand, for every town and village. In the red sandstone country most of our towns are situated. The characteristic red soil of this district is so soluble that streams having a large portion of their water-sheds upon it carry much sediment in the wet seasons. This, together with the density of population and the high state of cultivation, makes it difficult to secure a satisfactory supply from streams. Where they are used, more or less effectual attempts are made to clarify the waters. Five of the thirty water-works in the district draw their water from open wells. The supply from these wells has thus far been found satisfactory, but as they draw, invariably, either from boulder drift and gravel overlying the rock, or from upper strata, the danger of their gradual pollution is apparent, and great care should be exercised in their location. There are a few private driven wells in this area, but, in general, the result of boring or driving is extremely uncertain, and there have been many failures.

The clay and marl districts afford the fewest opportunities for obtaining satisfactory supplies for villages or towns. The surface-waters are charged with objectionable matter from the soil. On the extreme

southeast border, where it is possible to sink wells to the red-sand bed underlying the middle marl-bed, a good and bountiful supply can be obtained; but elsewhere the results of sinking wells are uncertain.

In the pine region there is an abundance of good water in the streams, with the additional certainty of finding an excellent supply by driven wells at a depth which can be very closely predicted. The latter fact is the solution of the problem of supplying the coast resorts which lie on isolated sand beaches.

The subject of water-supply will be fully taken up in Volume III. of the Final Report, which is now in course of preparation.

ARTESIAN WELLS.

The abundant supply of wholesome water obtainable by boring artesian wells is appreciated more and more, and such wells are put down for both private and public needs. The comparative economy of these wells is a strong point in their favor, and the almost absolute certainty of success in getting good water, particularly in the southern part of the State, makes this source of water-supply one which is becoming more popular as it is better known. Water-bearing strata are interbedded with impervious layers in the Cretaceous, Tertiary and recent formations, and the wells bored during the past decade have shown their geological position. From the accurate topographic maps the depth of those beds beneath the surface can be readily learned and the depth of boring necessary to reach a water-supply. The preceding Annual Reports have described their position and given their probable depth throughout the southeastern or coast belt of the State. The records of artesian wells also have been given, with figures showing their flow and the source of their supply. The reader is referred to these reports for full information upon this most important subject.

The following notes of wells put down during the year are added:

RED SANDSTONE PLAIN.

Messrs. P. H. & J. Conlan, of Newark, engineers and contractors for water-supply, report the following notes of wells bored by them in 1889:

1. R. G. Solomon's, foot of Wright street, Newark, and on the meadows. Depth, 320 feet, of which 180 feet was in quicksand and clay and 140 feet in red shale. The flow is 100 gallons of water per minute.

2. Illingworth's Steel Works, East Newark. One well is 35 feet deep and yields 60 gallons of water per minute. Another is 320 feet deep, of which 168 feet is through clay and quicksand and 132 feet in red shale. The yield is 100 gallons a minute.

3. New Jersey Oil Company's well, near plank road, Newark, is 200 feet deep. Quicksand and clay, 90 feet; red shale and sandstone, 110 feet. Yield is 50 gallons per minute.

4. Watch Case Factory, Roseville, near Newark city line. Well is 140 feet deep. Quicksand, 60 feet; red shale and sandstone, 80 feet. Yield is at the rate of 80 gallons a minute, and the quality is excellent.

5. Stewart Hartshorne, Short Hills. Well 180 feet deep, through sand and clay and gravel to top of the trap rock, and flowing at rate of 60 gallons per minute of excellent water.

6. J. C. Canniff, Verona. Well is 150 feet deep. Gravel, 20 feet; quicksand, 80 feet; slate, brown shale and trap rock. Yield is about 40 gallons per minute of good water.

7. Rising Sun Brewery, Elizabeth avenue, Elizabeth. Well is 300 feet deep. Red clay, 80 feet; red shale, 200 feet; red sandstone, 20 feet. Yield is 160 gallons per minute.

8. Linden Race Track. Twelve 2-inch wells, from 50 to 100 feet deep; one 6-inch well, 230 feet deep, in shale and sandstone. Yield of deep well is 45 gallons per minute.

FREEHOLD, MONMOUTH COUNTY.

Two artesian wells were bored in Freehold, in August and September, for the town water-supply. Their location is on Bennett street, adjoining the line of the Freehold and New York railroad. The hydraulic process in raising the material, prevented a careful study of the various beds which were passed through in the first well. The first stratum of water-bearing sand was reached at a depth of 135 feet. At 172 feet a black clay was met and it was not penetrated at 208 feet. At 255 feet, white sand, with fragments of wood, was found, and the boring was continued into this sand to a depth of 322 feet. The water rose to within 62½ feet of the surface.

A second well was put down 16 feet from the first one. The greensand marl was struck at 40 feet from the surface; at 58 feet, a black "marl" or clay, with sand; at 96 feet, a light-gray clay, to 102 feet, where there was a hard layer, 3 feet thick; then green "marl," 2 feet; another seam, 12 feet thick, of black and hard material; at 114 feet, a seam of gray "marl," with small shells; at 120 feet, a black deposit; at 127 feet, a layer of fine gravel or coarse sand; at 136 feet, fine sand, mixed with blue clay, and at 148 feet, the water-bearing sand was reached. The tube was driven 24 feet into it, making the whole depth of this well 172 feet. The capacity of the well in November, with a hand-pump, was found to be equivalent to a supply of 25 gallons a minute, or 36,000 gallons a day, limited, however, to the capacity of the pump only. The water rose to a level 26 feet from the surface, when the pumping was suspended.

An analysis of the water made by Prof. F. A. Wilber, showed that it contained 8.607 grains of total solids per gallon.

	Grains per gallon.
Silica	0.776
Sesquioxides of iron and alumina	0.017
Lime	3.084
Magnesia	0.303
Potash	0.116
Soda	0.349
Sulphuric acid (in sulphates)	0.245
Chlorine (in chlorides)	0.321
Total solids determined	5.211
Volatile and undetermined	3.396
Total solids (grains per gallon)	8.607
Hardness (equivalent to calcium carbonate)	5.479

The water is clear, tasteless, without smell and neutral (with reagents). The total solids is not high, but the percentage of lime is above that of the average in the waters of the artesian wells on the coast and of river-water generally, and is due to the bicarbonate of lime, and is, therefore, a hard water. But it is comparatively free from organic impurities, and is a wholesome drinking-water.

RED BANK, MONMOUTH COUNTY.

The following extracts from a letter from William S. Sneden, describe the discovery of an abundant additional water-supply in a

sand-bed, 230 feet below the surface, and 160 feet below that from which the present supply is obtained:

"RED BANK, N. J., November 30th, 1889.

"*Irving S. Upson, Esq.:*

"DEAR SIR—Referring to your letter of the 25th instant, I am glad to give you some information as to the increase in the water-supply for this town, obtained during the past year.

"Owing to the large quantity of water required by the railroads, the Commissioners decided to test the plan of boring to a stratum 160 feet below that from which the water had been obtained (which was immediately under the lower marl-bed), and if the water was found as it had been at Asbury Park, Seabright and elsewhere, and should rise to a sufficient height, to syphon it into the big well of the works.

"The enterprising well borers, Kisner & Bennett, undertook the contract, and found the stratum as expected, which is a bed of fine white sand, in which is imbedded logs of wood about 230 feet below the surface, or 160 feet below the water-bearing stratum underlying the lower marl-bed as above mentioned.

"Three pipes were sunk at intervals of from three to four hundred feet, and the water rose in each to within 10 feet of the surface of the ground. Pipes were carried to the big well (in which the vertical pumps are placed) under ground and down into the well some 35 or 40 feet and a vacuum produced, starting the water running on the principle of the syphon and furnishing a large supply. This demonstrates the fact that any additional supply which may be needed can be obtained and the water is pure and delicious.

"Yours truly,

(Signed) "WM. S. SNEDEN."

The result in this last boring has importance in proving the existence of water-bearing layers in the clay marls.

FELLOWSHIP, BURLINGTON COUNTY.

J. G. Williams had a well bored on his farm a quarter of a mile north of Fellowship, and on the road to Wilson's Station, in 1888, which at a depth of 131 feet pierced a layer of coarse white gravel, and from which there was a good flow of water. It rose to within 50 feet of the surface. Under the gravel a bed of marl with fine running sand was driven through down to 200 feet, the last 8 feet in a second layer of gravel. The boring was continued to a depth of 260 feet, and through a bed of "kaolin," which was troublesome in pumping and at last closed the pipe. The marl-bed passed through about 20

feet below the surface is the lower marl-bed. The marl under the gravel at 131 feet belongs to the clay marls, and the bottom of the well was near the base of that member of the cretaceous series. The closing of the pipe by the "kaolin" stopped the work.

CINNAMINSON, BURLINGTON COUNTY.

Alexander C. Wood put down a six-inch well on his farm in Cinnaminson township and a quarter of a mile east of the post-office. The strata passed through were as follows:

Earth	6 feet.
Shell	1 foot.
Yellow sand	20 feet.
Fine white gravel	3 feet.
Yellow clay	2 feet.
Whitish sand	10 feet.
Coarse white gravel	4 feet.

The well yields 400 to 500 gallons per minute, and the water has a temperature of 52 degrees.

SEWELL, CAMDEN COUNTY.

An artesian well bored in September on the lands of Fred. J. Anspach, of Philadelphia, on Chew's hill, east of Mantua road, passed through the following strata:

Surface layers	17 feet.
Green marl	7 feet.
Black marl	6 feet.
Shell rock	6 feet.
Sand rock	7 feet.
Sand	13 feet.
Shells, &c.	....
Coarse sand with black specks	16 feet.
	72 feet.

Pumping at the rate of 120 gallons per hour did not lower the column of water. The water depth remained 29 feet after pumping. The water is said to be clear and of satisfactory quality. Tests

showed that it was neutral in behavior, with reagents. The water comes from the red-sand bed underlying the middle marl-bed.

BAYSIDE, CUMBERLAND COUNTY.

Maskell Ewing, President of the American Oil and Refinery Company, reports the following relative to a well at Bayside, bored by his company: After getting down nearly 100 feet we struck a salt spring, which flowed 18 inches above the level of the marsh, and probably two feet above high water, and was not affected by the rising and falling of the tide. The spring was lost, but another was struck after going about 140 feet; this was also very salt, cold and clear. The first 33 feet was mud; we then struck a thin layer of probably 18 inches of a hard clay. At a depth of 160 feet a hard clay was encountered, and the work was stopped by the breaking of the pipe. The site of this boring is in the marsh, and about a quarter of a mile from the upland.

NORMANDY HOTEL, NEAR SEABRIGHT, MONMOUTH COUNTY.

Kisner & Bennett bored the wells at this place. The water is good, but hard. The sand in which these wells get their water-supply is 120 feet below the bottom of the lower marl-bed, and is 40 feet thick. It is very fine, and is underlain by a black clay. The pipe is bored with five eight-inch holes, and sheathed with wire gauze for 40 feet—the length in sand. The flow of water is at the rate of 55 gallons a minute. These wells are in the clay-marl series of beds. (See Annual Report for 1888, page 73.)

MANTOLOKING, OCEAN COUNTY.

A well bored by Kisner & Bennett, at the Mantoloking Hotel, is 175 feet deep to bottom of the upper marl-bed. A three-inch pipe was used, and the water rose 35 feet above the surface.

WELLS BORED BY F. & W. STOTHOFF, FLEMINGTON.

F. & W. Stothoff, Flemington, report the following list of wells bored by them during the year 1889, with their statistics of depth, strata and volume of water:

NEWTON, SUSSEX COUNTY.

35 feet, limestone.................................... 250 gallons per hour.

CLINTON, HUNTERDON COUNTY.

(1) 40 feet, limestone.................................... 300 gallons per hour.
(2) 64 feet, limestone.................................... 100 " "

GLEN GARDNER, HUNTERDON COUNTY.

22 feet.................................... 600 gallons per hour.

BLOOMSBURY, HUNTERDON COUNTY.

35 feet, granite.................................... 400 gallons per hour.

PATTENBURG, HUNTERDON COUNTY.

54 feet, red shale.................................... 350 gallons per hour.

LAMBERTVILLE, HUNTERDON COUNTY.

Pennsylvania Railroad Company's shops, and near the Delaware river, sand and earth, 20 feet; "gray rock," 65 feet.................................... 2,000 gallons per hour.

FLEMINGTON, HUNTERDON COUNTY.

(1) Lehigh Valley Railroad Company, 42 feet......... 1,000 gallons per hour.
(2) Green-house, 150 feet.................................... 1,000 " "
(3) 63 feet.................................... 1,600 " "

NOTE.—5 to 10 feet earth, then red shale and sandstone.

ROSELLE, UNION COUNTY.

Lehigh Valley Railroad Company, 50 feet............... 600 gallons per hour.

PASSAIC.

(1) 100 feet.................................... 1,000 gallons per hour.
(2) 180 " .... 600 " "
(3) 317 " .... 400 " "
(4) 175 " .... 1,200 " "
(5) 49 " .... 300 " "
(6) 100 " .... 300 " "
(7) 187 " .... 3,000 " "

In eastern part of the town the red sandstone is at a depth of 100 to 125 feet below the surface; in the western part it is 30 to 60 feet deep.

Two wells near Passaic, each 50 feet, and volume. ... 500 gallons per hour.

RIVERTON, BURLINGTON COUNTY.

50 feet, sands.................................... 600 gallons per hour.

MEDFORD, BURLINGTON COUNTY.

Sand and earth, 15 feet; marl, 30 feet; sands, varying, 15 feet; shelly layer, 4 feet; coarse gray sand, 6 feet.. 1,200 gallons per hour.

ANDALUSIA, BUCKS COUNTY, PENNSYLVANIA.

50 feet, mica rock .... 650 gallons per hour.

SCHENCK'S STATION, BUCKS COUNTY, PENNSYLVANIA.

51 feet, mica rock .... 200 gallons per hour.

ARTESIAN WELLS, ATLANTIC CITY, N. J.

BY LEWIS WOOLMAN.

During the past three or four years the Consumers' Water Company of Atlantic City have had put down four artesian wells, of which the first and fourth have been successful in obtaining water. The first three were sunk by J. H. Moore, of Atlantic City, and the fourth by P. H. & J. Conlin, of Newark, N. J.

Believing that a knowledge of the character and succession of strata would be of permanent value both economically and scientifically, I have, as the work progressed, made a careful study of the borings, the results of which I now embody. Their attainment is due to the courtesy of three members of the company, Dr. T. K. Reed, Joseph Borton and F. W. Helmsley, in providing every facility for geological investigation and also to the co-operation of the two contractors and their assistants in carefully saving specimens from three of the wells every few feet.

Valuable assistance has also been rendered in scientific circles. In this direction thanks are due to Prof. A. Heilprin, for aid in geology and paleontology, and to C. Henry Kain and E. A. Schultze, for their joint labors in the identification of species of diatoms. Dr. D. B. Ward, of Poughkeepsie, N. Y., and C. L. Peticolas, of Richmond, Va., have also aided the author greatly in these studies. The former made many micro-photographs of diatoms, and the latter numerous cleanings of the same illustrating the general assemblage of forms and the especial features of the various depths.

Well No. 1 was sunk near the southeast corner of Michigan and Arctic avenues. It reached approximately a depth of 1,150 feet and pierced a stratum at about 1,100 feet from which fresh water flowed to five feet or more above the surface, which at this point is eight feet above tide. This water has since 1887 been supplied through street mains to many hotels and cottages. The well is cased with an eight-inch pipe to 746 feet and then with a six-inch pipe inside this to just above the water stratum.

The other three wells are located near the southeast corner of Kentucky and Adriatic avenues, on a knoll within the meadows. They are distant 2,200 feet almost northwest from Well No. 1.

Well No. 2 has a ten-inch bore, and was abandoned at about 315 feet, on account of an accident.

Well No. 3 was started about ten feet from the last, and attained a depth of 1,400 feet, being, it is believed, the deepest bore along the Atlantic coast north of Charleston, S. C. It is cased with a ten-inch tube to 466 feet. This was reduced to an eight-inch from that depth to about 800 feet. Here the casing was again reduced to a six-inch, which continued to 1,188 feet; while below this the size of the casing was only 4½ inches.

Success not attending the efforts to obtain water, the boring was discontinued, and the pipes are now being withdrawn, hoping to develop some of the water-bearing strata that were undoubtedly passed through, though probably in a partially closed condition.

The wells so far described were put down by the use of the drill and sand-pump, the usual method in rock countries, and an especially good one for the procuring of an accurate series of samples.

Well No. 4 has a diameter of eight inches, and is situated about 100 feet east of Wells Nos. 2 and 3. It was bored by the hydraulic process, in which a drill is used, having a hollow body, with perforations near the cutting end. To the body, as the work progresses, section after section of tubing is added. Down this tubing water is forced under pressure through the perforations, and rises between the tube and the casing, bringing up with it the loosened material from the bottom. This process is much used along the New Jersey coast. This well has a depth of 578 feet, and pierced four strata, from which water flowed over the top of the casing a few feet above the ground. These were at 328, 406, 429 and 554 feet respectively. The streams from 328 and 406 feet were pumped; the former yielded about 50

gallons a minute, and the latter not more than 10 gallons. The water from both at first tasted quite pure and fresh, but on pumping both unaccountably became salty. These strata were, therefore, each in turn cased off. On account of the toughness of the clay-beds below 383 feet, the casing could not be driven further than 424 feet, and the balance of the boring was continued without casing, the walls remaining intact without such protection. The other two water levels are both below this casing. That at 429 feet was a diminutive stream, but that at 554 feet, I am informed, flowed 50 gallons a minute, and produced, on pumping, 150 gallons, which has since increased to 200 gallons. It has now been pumped several weeks, and proves to be good, fresh water. It is agreeably pleasant to the taste, and, in this respect, is much like that at Pleasant Mills.

The water-bearing stratum at 328 feet is located between clay-beds in a reddish-brown sand section; the other three water strata are in sand partings within a thick clay section—the lowest of these occupies the interval between 554 and 560 feet.

Well No. 1 was nearly completed before I became aware of the fact. I, however, obtained, at that time and later, a number of fossils saved therefrom, and after the work was finished collected many more by turning over the sands and clays heaped up at the mouth of the well. From an examination of these, in connection with a record furnished by the contractor, I made as full a report as was practicable to the Academy of Natural Sciences, Philadelphia, in the latter part of the year 1887.

On learning of the intended sinking of other wells, I arranged with J. H. Moore for the preservation of a complete series of earths every few feet; these were placed in small dairy-salt sacks having already attached Dennison's shipping tags, on which the description and depth of each specimen were written at the time, and the sacks at once securely tied up and laid aside. By an examination of these the number of fossil forms similar to those which had previously been listed in the report just alluded to, was about doubled. These include 82 species of mollusks, a few corals, also sharks' teeth and other fish teeth and scales, spines of sea urchins, barnacles, crabs' claws, and a bone of an animal of the crocodile order.

There were also discovered about 175 micro-organisms that had escaped detection in Well No. 1, though a more recent searching among the material from that well has resulted in finding them there also.

The earths saved by J. H. Moore were from Wells Nos. 2 and 3; in addition to these, P. H. & J. Conlin saved many washings from Well No. 4. The total number of samples thus procured was 221.

The specimens from the different wells have been collated with each other and compared with a carefully-kept record for Well No. 3, furnished by J. H. Moore. The results and deductions from this examination it is intended now to present.

For this purpose a columnar section has been prepared. On its left is a minute description of the various changes in strata and the thickness of each, this being in fact the record furnished by J. H. Moore, copied verbatim, except that some slight corrections in the thickness of some of the beds have been made to harmonize with the depths obtained from Well No. 4, but never amounting in any instance to more than five feet. A few insertions of facts learned from each of the other wells have been made; these are bracketed thus: ( ).

On the right is a more general description exhibiting the grouping of the strata into larger divisions, having certain broad characteristics. In this are noted the occurrence of the various fossiliferous horizons, with the specific names of a few of the fossils, because of their geological value.

For convenience, these larger divisions have been lettered, and a corresponding letter will appear at the head of each of the succeeding paragraphs referring again to the same.

A. Surface to 45 feet. The blue mud at the base of this division was probably at the bottom of an old thoroughfare, that became afterward covered over by sand. The shells noted were the ordinary oyster, clam and scallop of the bays, and were of course fossil. In the fossil state was also found one form of *Foraminifera* (a *Nonionina*) identical with the only living species I have been able to find on the beach.

B. 45 feet to 265 feet. The "coarse gravel and large stones" at 45 to 55 feet, were of quartz, some of them one to two inches in diameter. Similar pebbles were found in a well at Sea Isle City at about the same depth and also in gravel pits in the bank east of Absecon, five miles from the well.

The gravels at 84 to 116 feet, described as containing "petrified shell," were fossiliferous pebbles, such as have frequently been found

elsewhere in the State, and now known to have been derived from Devonian and Silurian rocks. Similar pebbles bearing fossils occur near Germania, 14 miles northwest, elevated 60 feet above sea level. They are also very plentiful in gravel pits at Straffordville, above Tuckerton, at about the same elevation, and directly in the line of strike of the New Jersey strata from Pomona.

At 228 feet fossiliferous pebbles again occurred in one of the wells, though not observed in the others.

Certain gravels and sands at about 150 feet apparently repeat themselves on a hill northeast of Ellwood, elevated 120 feet. Specimens from each locality are entirely undistinguishable.

C. 265 feet to 383 feet. The deposits of the preceding section have generally been regarded as belonging to the Quaternary division of geological time. At about 265 feet we pass from these to underlying Miocene-beds having an increased, though still gentle dip to the southeast. In this section water flowed to the surface from 328 feet, as before noted. Excepting two clay-beds, each about 5 feet thick, this division is mainly composed of reddish-brown sands varying from light in shade at the top to quite dark at the base.

D. 383 feet to 658 feet. Succeeding the red sands just described occurs the thickest of all the beds encountered (except possibly the lowest, which was not passed through), being 275 feet in vertical extent. Leaving out a few sand partings, not more than one to ten feet thick, this entire division is made up of clays, some sandy and some quite pure. When dry, as in the samples preserved, they are generally gray in color, but when wet, as when brought out by the sand pump, they are blueish, greenish and brownish in appearance, and thus agree with the descriptions to the left of the column. It is from the sands of this section that three of the water-flows were obtained.

These clays throughout their whole extent are largely composed of the siliceous remains of a low order of micro-botanic forms known as diatoms. These probably constitute about 20 per cent. of the body of the clay in the richest portions.

When considered as to thickness, and in other respects, this is certainly the most remarkable diatomaceous deposit yet discovered in the world. These minute siliceous skeletal plant remains have long been well known as among the most beautifully and delicately marked of

microscopic objects. They are of circular, oval, triangular, elongated, and various other shapes. They are transparent and of pure quartz, and are constructed with two opposing convex frustules or valves. They will withstand any amount of treatment with acids, in which they are boiled to clean and separate them from the other ingredients of the clay. C. L. Peticolas has thus prepared for the writer's examination about 30 cleanings from as many different depths. These show the diatoms to exist throughout the whole bed, except only in the pure sand seams, where there were none—the purer the clay, the richer in diatoms; the more sandy the clay, the poorer in diatoms.

The richest portions were at 400, 525 and 625 feet. Some forms occur through the whole section, while some are characteristic mainly of some one depth and scarcely, if at all, seen elsewhere. This is especially noticeable of a beautiful, iridescent, many-rayed form (*Actinocyclus Ehrenbergii*) at 625 feet. As may be inferred, these diatoms were salt-water forms, though a very few fresh-water forms were found; the latter would indicate the influence of a fresh-water estuary. One of the marine forms has heretofore been known only from the tropics.

C. Henry Kain and E. A. Schultze have identified about 150 species distributed among 49 genera. They have also named, figured and described several new forms in the Bulletin of the Torrey Botanical Club, Vol. 16, pages 71 to 76, and pages 207 to 210—Plates LXXXIX., XCII. and XCIII. One of these was named in honor of the late Prof. George H. Cook. (*Triceratium Cookiana.*)

C. L. Peticolas has now in preparation a beautiful representative series of mounts from about twelve different depths. They are worthy a place in the cabinet of every microscopist.

Associated with the diatoms were a number of sponge spicules, some of them of the pin-head form, characteristic of salt water only.

Considerable comminuted shell was also associated with the diatoms at 430 to 480 feet; it is now impossible to determine whether these were in that condition in the clay or whether they were ground up by the drill; the hardness of the clay and the consequent difficulty of drilling would favor the latter supposition. A few fragments of clam and some of other shells were obtained at 540 feet, but these were so worn in some cases and so broken in others that species could not be made out. One, however, was either a modiola or a mytilus.

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No. 11. Vicinity of Camden, to Burlington, Winslow, Elmer and Swedesboro.
No. 12. Vicinity of Mount Holly, from Bordentown southward to Winslow and Woodmansie.
No. 13. Vicinity of Barnegat Bay, with the greater part of Ocean county.
No. 14. Vicinity of Bridgeton, from Allowaystown and Vineland southward to the Delaware bay shore.
No. 15. Southern Interior, the country lying between Atco, Millville and Egg Harbor City.
No. 16. Egg Harbor and Vicinity, including the Atlantic shore from Barnegat to Great Egg Harbor.
No. 17. Cape May, with the country westward to Maurice river.
No. 18. New Jersey State Map. Scale, 5 miles to an inch. Geographic.
No. 19. New Jersey Relief Map. Scale, 5 miles to the inch. Hypsometric.
No. 20. New Jersey Geological Map. Scale, 5 miles to the inch.

In order to meet the constantly increasing demand for these sheets, the Board of Managers of the Geological Survey have decided to allow them to be sold at the cost of paper and printing, for the uniform

H. 955 feet to 1,095 feet. Then succeeds 140 feet of a peculiar greenish-yellow sand, with many streaks of loam and filled with barnacles throughout; a few shallow-water shells were also found. The fossils in this sand show a period of elevation and a shallow sea, as conditions existing at the time. Near or just below the base of the section, the water-stratum of Well No. 1 was reached, though it failed to yield water in Well No. 3. It is of the same quality by chemical analysis as the water from the artesian well at Winslow.

I. 1,095 feet to 1,225 feet. This section is composed of a series of marly clays and true marls. There are two beds of the latter, 20 and 55 feet in thickness. *Cardita granulata*, a Miocene fossil, was obtained at 1,180 feet.

K. 1,225 feet to 1,400 feet. This is the lowest bed encountered and is of one character, a tough, tenacious clay, from top to bottom, except that as to color it shades from light to dark slate; this bed was not passed through, the drilling being stopped within it in a whitish stratum. It contains an abundance of *Foraminifera*, comprising, so far as observed, 14 genera, all very nearly if not quite identical in species with forms described and figured by D'Orbigny about 1846, from the clays around Vienna, Europe. It also contains *Placocyathus*, a deep-sea coral very similar to an undescribed form collected by W. M. Gabb from the Miocene of San Domingo, and now in the museum of the Academy of Natural Sciences, Philadelphia.

There is much iron pyrites in this clay filling the interior, in some cases of fossils, which, however, could not be identified on account of imperfect condition. This section shows a period of depression of the coast border and a deep sea when the deposit was laid down.

As a result of these well-borings we now learn that the Quaternary gravels and sands spread over New Jersey have a thickness of over 200 feet (220 feet in the well). The evidence presented by the fossils as to the strata below these gravels and above 1,225 feet is decidedly for their Miocene age. Below this there is no fossil distinctive of the eocene, while the few forms found lean so towards the Miocene that it seems impossible to arrive at any other conclusion than that the entire series below the Quaternary gravels belongs to the same age—that is, the Miocene.

The Miocene of the Atlantic seaboard has been classified into three divisions—an upper, lower and middle Atlantic. The upper occurring in South and North Carolina, while the middle and lower appear in both Virginia and Maryland. The fossils in the well indicate that the strata generally belong to the lower Miocene; but the occurrence of *Tunitella plebeia* at the top only of the Shiloh beds, and also in a well at Cape May point, from a probable depth of 400 feet, where it is associated with *Melanopsis Marylandica,* heretofore found at the mouth of the St. Mary's river, would render it probable that the upper portion of these Miocene strata belong to the middle Atlantic division.

This shows a thickening of Miocene deposits, and a consequent greater unconformability between these and the underlying eocene and cretaceous beds, with a greater dip for the latter in south New Jersey than has heretofore been thought to be the case, for if the views previously held were correct, the base of the well ought to be in the cretaceous, but the borings present contrary evidence.

Respecting the amount of dip of the various strata toward the southeast, the data already presented would indicate for the yellow gravels a dip of from 12 to 15 feet per mile.

Assuming the 554 to 560-feet stratum to be the equivalent of the water-bearing sand at Pleasant Mills, which is 34 feet below sea level, and 22½ miles distant, measured at right angles to the strike of the New Jersey cretaceous series, we have a dip of 24 feet to the mile.

The Shiloh marl outcrop, measured in the same manner, is 35 miles distant, and 60 feet above tide, and as these beds occur in the well at, say, 750 feet, we have from this a dip of 23 feet per mile.

The Winslow well and the 1,100-feet stratum in Well No. 1, furnished the same quality of water as before stated, and the record for each reckoning, from the bottom upward, shows a similarity of succession of strata up to a micaceous sand, noted in both, except that the beds are thicker in the Atlantic City well. It therefore appears probable that the water-bearing strata in each represent the same horizon. The calculation for the dip of this stratum is 30 feet per mile.

When we consider the oscillations of land and sea level, the change in the lower part of the well, at about 1,100 feet from shallow water-beds to deepening sea-beds, and the unexpected thickness of the lowest bed, we may suspect that the strata at 1,400 feet have a still greater dip.

I have already noted for the upper portion of the Miocene strata a dip of 23 and 24 feet to the mile. It may be of interest to note how nearly this harmonizes with Prof. Cook's opinion and prediction expressed beforehand. In a letter to the contractor, previous to the commencement of Well No. 4, he says: "I send you a geological map, on which I mark several wells now supplying water and which I think draw their supply from the stratum which should supply Atlantic City." After excepting "Harrisville, because it is not running," he names the others, and their distance from Atlantic City, measured at right angles to the lines of strike, with their depth below sea level, as follows:

"Pleasant Mills	22½	miles	N. W.	Atlantic City,	and	34	feet	deep.
Weymouth	19½	"	"	"	"	15	"	"
Barnegat	15½	"	"	"	"	120	"	"
Mays Landing	15	"	"	"	"	142	"	"
Harvey Cedars	11¼	"	"	"	"	240	"	"
Seven Islands	6½	"	"	"	"	408	"	"
South Beach Haven	5½	"	"	"	"	425	"	" "

And then continues, "These wells all supply the same quality of good water, and I judge that they draw from the same water-bearing stratum. The measurements of depths are of course somewhat variable, and there seems a slight irregularity between Pleasant Mills and Weymouth, but, taking them all together, and they are all that I know of,* there is a descent from the northwest toward the southeast; and using these figures for computation, the descent averages 26 feet per mile, with extremes of 20 and 30 feet. If now we take Seven Islands well, which is the nearest to Atlantic City, at 26 feet per mile, water should be found at Atlantic City at a depth of 577 feet, and between the extremes of 538 feet, minimum, and 603 feet, maximum, the stratum should be very carefully sought for. There is certainly a water-bearing stratum at something near that depth. It may be very nearly closed, but it is there, and may possibly be opened, if it is in that partially-closed condition."

I would suggest, in view of the number of levels from which

* To these might have been added two wells then flowing, of which information seems not to have reached Prof. Cook—they are below Port Norris, on either side of Maurice river near its entrance into Delaware bay. Their depths are stated to be—for the one on the western bank, 190 feet, and for the one on the eastern bank, 210 feet; they are distant from Atlantic City, measured in the same manner as above, 10¾ miles, and are very nearly in the line of strike with Harvey Cedars.

water flowed to the surface in the Atlantic City well, whether this may not account for the differences in dip and some irregularities, though there may also be some unevenness of the old sea-bottoms. If a series of samples and careful records could be obtained from future wells in the southern part of the State, these irregularities and apparent discrepancies might be fully explained.

The diatomaceous clay and the *Perna* shell and marl-beds are closely related to similar beds in Maryland and Virginia—the latter being the extension southward of the same group of strata; the exact continuance, however, of any one single bed in the group has not yet been traced. The city of Richmond, Virginia, is underlaid by about 80 feet of similar clays, of which the upper 20 feet are more or less richly diatomaceous. Diatom deposits, 10 feet or more in thickness, outcrop on the Potomac and the Patuxent rivers, and on the western shore of Chesapeake bay. On the eastern shore diatoms have been found, as before noted, at a depth of 275 feet, in an artesian well at Cambridge, Maryland, and at a few outcrops on the bay shore. At all these localities diatomaceous strata are either seen under beds containing *Perna* and other Miocene shells, or else they outcrop to the westward of such shell-beds, and therefore belong below the same, while in the Atlantic City well the diatom strata occur above *Perna* beds. I can scarcely resist the conclusion, however, from a very considerable study of microscopic mounts, that the diatom-beds at 525 feet in the Atlantic City well, at 275 feet in the Cambridge well, and 558 feet in the Fortress Monroe well are one and the same, but this would require the existence of more than one shell stratum containing *Perna*, which is probably the case, though the proof remains for future investigation and demonstration.

VI.

PUBLICATIONS OF THE SURVEY.

GEOLOGY OF NEW JERSEY, Newark, 1868. 8vo. xxiv.+899 pp.
Out of print.

PORTFOLIO OF MAPS accompanying same, as follows:

1. Azoic and paleozoic formations, including the iron-ore and limestone districts; colored. Scale, 2 miles to an inch.
2. Triassic formation, including the red sandstone and trap-rocks of Central New Jersey; colored. Scale, 2 miles to an inch.
3. Cretaceous formation, including the Greensand marl-beds; colored. Scale, 2 miles to an inch.
4. Tertiary and recent formations of Southern New Jersey; colored. Scale, 2 miles to an inch.
5. Map of a group of iron mines in Morris county; printed in two colors. Scale, 3 inches to 1 mile.
6. Map of the Ringwood iron mines; printed in two colors. Scale, 8 inches to 1 mile.
7. Map of the Oxford Furnace iron-ore veins; colored. Scale, 8 inches to 1 mile.
8. Map of the zinc mines, Sussex county; colored. Scale, 8 inches to 1 mile.

A few copies are undistributed.

REPORT ON THE CLAY DEPOSITS of Woodbridge, South Amboy and other places in New Jersey, together with their uses for fire brick, pottery, &c. Trenton, 1878, 8vo., viii.+381 pp., with map.
Out of print.

A PRELIMINARY CATALOGUE of the Flora of New Jersey, compiled by N. L. Britton, Ph.D. New Brunswick, 1881, 8vo., xi.+233 pp. Out of print.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. I. Topography. Magnetism. Climate. Trenton, 1888, 8vo., xi + 439 pp.

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No. 11. Vicinity of Camden, to Burlington, Winslow, Elmer and Swedesboro.
No. 12. Vicinity of Mount Holly, from Bordentown southward to Winslow and Woodmansie.
No. 13. Vicinity of Barnegat Bay, with the greater part of Ocean county.
No. 14. Vicinity of Bridgeton, from Allowaystown and Vineland southward to the Delaware bay shore.
No. 15. Southern Interior, the country lying between Atco, Millville and Egg Harbor City.
No. 16. Egg Harbor and Vicinity, including the Atlantic shore from Barnegat to Great Egg Harbor.
No. 17. Cape May, with the country westward to Maurice river.
No. 18. New Jersey State Map. Scale, 5 miles to an inch. Geographic.
No. 19. New Jersey Relief Map. Scale, 5 miles to the inch. Hypsometric.
No. 20. New Jersey Geological Map. Scale, 5 miles to the inch.

In order to meet the constantly increasing demand for these sheets, the Board of Managers of the Geological Survey have decided to allow them to be sold at the cost of paper and printing, for the uniform

price of 25 cents per sheet, either singly or in lots. This amount covers all expense of postage or expressage, as the case may be. Sets of the sheets, bound in atlas form (half morocco, cloth sides, gilt title, maps mounted on muslin, and guarded), are furnished at $13.50 per copy. Application and payment, invariably in advance, should be made to Mr. Irving S. Upson, New Brunswick, N. J., who will give all orders prompt attention.

REPORT OF PROFESSOR GEORGE H. COOK upon the Geological Survey of New Jersey and its progress during the year 1863. Trenton, 1864, 8vo., 13 pp. Out of print.

THE ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to His Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1864. Trenton, 1865, 8vo., 24 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to His Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1865. Trenton, 1866, 8vo., 12 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, on the Geological Survey for the year 1866. Trenton, 1867, 8vo., 28 pp. Out of print.

REPORT OF THE STATE GEOLOGIST, Prof. Geo. H. Cook, for the year 1867. Trenton, 1868, 8vo., 28 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1869. Trenton, 1870, 8vo., 57 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1870. New Brunswick, 1871, 8vo., 75 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1871. New Brunswick, 1872, 8vo., 46 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1872. Trenton, 1872, 8vo., 44 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1873. Trenton, 1874, 8vo., 128 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1874. Trenton, 1874, 8vo., 115 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1875. Trenton, 1875, 8vo., 41 pp., with map.

ANNUAL REPORT of the State Geologist of New Jersey for 1876. Trenton, 1876, 8vo., 56 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1877. Trenton, 1877, 8vo., 55 pp.

ANNUAL REPORT of the State Geologist of New Jersey for 1878. Trenton, 1878, 8vo., 131 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1879. Trenton, 1879, 8vo., 199 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1880. Trenton, 1880, 8vo., 220 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1881. Trenton, 1881, 8vo., 87+107+xiv. pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1882. Camden, 1882, 8vo., 191 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1883. Camden, 1883, 8vo., 188 pp.

ANNUAL REPORT of the State Geologist of New Jersey for 1884. Trenton, 1884, 8vo., 168 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1885. Trenton, 1885, 8vo., 228 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1886. Trenton, 1887, 8vo., 254 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1887. Trenton, 1887, 8vo., 45 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1888. Camden, 1889, 8vo., 87 pp., with map.

ANNUAL REPORT of the State Geologist of New Jersey for 1889. Camden, 1889, 8vo., 112 pp., with cut.

VII.
PERSONS EMPLOYED.

C. Clarkson Vermeule, C.E., has carefully attended to the revised edition of the "Atlas of New Jersey," which was distributed to the public free schools of the State during the year.

Frank L. Nason, A.M., has been engaged as Assistant Geologist, giving most of his time throughout the year to field-work upon the Archæan.

Walter F. Ferrier, B.A.Sc., has been engaged as assistant in the Geological Survey, since July, devoting his time, chiefly, to a re-examination of a portion of the Clay District of Middlesex county.

Frederick A. Canfield, E.M., prepared the Catalogue of Minerals found in New Jersey, Prof. John B. Smith, the Catalogue of Insects, and Prof. Julius Nelson, Ph.D., the Catalogue of Vertebrates, for the second volume of the Final Report.

James W. Thompson, George C. Bullock, Alfred A. Cannon and Charles M. Dixon rendered faithful and efficient service in the distribution of the publications of the Survey to the public free schools.

Frank R. Van Horn was employed for about six weeks in collecting rock specimens, under the direction of the Assistant Geologist, Prof. Nason.

Hatfield Smith has been in the employ of the Survey since April 1st. His time has been occupied in cutting thin sections of rocks and in other work, such as arranging and packing rock specimens.

Frederick S. Smith and Paull J. Challen have been employed for short periods of time in surveying, and the former also in mapping the results obtained.

Messrs. Austen and Wilber have made the analyses and done other chemical work of the Survey.

VIII.

EXPENSES.

The expenses of the Survey have been kept strictly within the annual appropriation of $8,000, and its bills are all paid.

IX.

STATISTICS OF IRON AND ZINC ORES.

IRON ORE.

The output of the iron mines of the State for the year 1889, as shown by the shipments of iron ore from stations in the State and the amounts used at furnaces which do not come in the tonnage of the railroad lines, aggregated 482,169 tons—an increase of 34,431 tons as compared with the production of 1888. For the convenience of reference the statistics of iron ore mined in the State for the years 1870–1888, inclusive, are here inserted in a tabular form. Estimates and U. S. census figures at intervals back to 1790 are also given at the head of the column:

1790	10,000 tons	Morse's estimate.
1830	20,000 tons	Gordon's Gazetteer.
1855	100,000 tons	Dr. Kitchell's estimate.
1860	164,900 tons	U. S. census.
1864	226,000 tons	Annual Report State Geologist.
1867	275,067 tons	" " "
1870	362,636 tons	U. S. census.
1871	450,000 tons	Annual Report State Geologist.
1872	600,000 tons	" " "
1873	665,000 tons	" " "
1874	525,000 tons	" " "
1875	390,000 tons	" " "
1876	285,000 tons*	
1877	315,000 tons*	
1878	409,674 tons	" " "
1879	488,028 tons	" " "
1880	745,000 tons	" " "
1881	737,052 tons	" " "
1882	932,762 tons	" " "
1883	521,416 tons	" " "
1884	393,710 tons	" " "

* From statistics collected later.

1885	330,000 tons	Annual Report State Geologist.
1886	500,501 tons	" " "
1887	547,889 tons	" " "
1888	447,738 tons	" " "
1889	482,169 tons	" " "

This tabular statement shows that from 1870 to 1874 there was a gradual and steady increase in the annual production. The financial depression in the latter part of 1873 marked a turn in the rate of production, and the lowest output for the decade was reached in 1876. The product for 1877 was slightly in excess of that of 1876, and from that year onward there was a gradual rise to the boom of 1879, which showed itself in the large increase in 1880. The maximum was attained in 1882.

ZINC ORE.

The product of the zinc mines for the year 1889, as shown by the shipments over the transporting lines, was 56,154 tons.

The following tabular statement shows the production of the zinc mines of New Jersey for a number of years:

	Estimated tons.	
1868	25,000	Annual Report State Geologist.
1869		
1870		
1871	22,000	" " "
1872		
1873	17,500	" " "
1874	13,500	" " "
1875		
1876		
1877		
1878	14,467	" " "
1879	21,937	" " "
1880	28,311	" " "
1881	49,178	" " "
1882	40,138	" " "
1883	56,085	" " "
1884	40,094	" " "
1885	38,526	" " "
1886	43,877	" " "
1887	50,220	" " "
1888	46,377	" " "
1889	56,154	" " "

INDEX.

A.